COMPARATIVE EVALUATION OF STRESS DISTRIBUTION AROUND SINGLE PIECE AND TWO PIECE TITANIUM AND ZIRCONIUM IMPLANTS - A THREE DIMENSIONAL FINITE ELEMENT ANALYSIS - AN INVITRO STUDY

Dissertation Submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH I

PROSTHODONTICS AND CROWN & BRIDGE

APRIL 2015

CERTIFICATE

This is to certify that this dissertation entitled **"COMPARATIVE ELVALUATION OF STRESS DISTRIBUTION AROUND SINGLE PIECE AND TWO PIECE TITANIUM AND ZIRCONIUM IMPLANTS- A THREE DIMENSIONAL FINITE ELEMENT ANALYSIS- AN INVITRO STUDY"** *is a bonafide research work done by* **Dr.D.J.Shine Manoj** *under my guidance during his postgraduate study period between* ***2012 – 2015.***

This Dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**, *in partial fulfillment for the degree of* **MASTER OF DENTAL SURGERY in PROSTHODONTICS AND CROWN & BRIDGE - BRANCH I.** *It has not been submitted partially or fully for the award of any other degree or diploma.*

GUIDE:

Dr.T.J.Suneetha,M.D.S.,
Professor and Head of the Department,
Department of Prosthodontics and
Crown & Bridge,
Rajas Dental College & Hospital,
Thirunelveli.

CO- GUIDE:

Dr.Somasundaram, M.D.S.,
Reader,
Department of Prosthodontics and Crown
& Bridges,
Rajas Dental College & Hospital,
Thirunelveli.

ENDORSEMENT BY PRINCIPAL / HEAD OFTHE INSTITUTION

This is to certify that this dissertation entitled **"COMPARATIVE ELVALUATION OF STRESS DISTRIBUTION AROUND SINGLE PIECE AND TWO PIECE TITANIUM AND ZIRCONIUM IMPLANTS- A THREE DIMENSIONAL FINITE ELEMENT ANALYSIS- AN INVITRO STUDY"** is a bonafide research work done by **Dr.D.J.Shine Manoj** under the guidance of **Dr.T.J.Suneetha, M.D.S.**, Professor and Head**,** Department of Prosthodontics and Crown & Bridge, Rajas Dental College and Hospital, Kavalkinaru, Tirunelveli-627105.

Date :

Place : Kavalkinaru

Dr.MARY KUTTY JOSEPH M.D.S,
Principal
Rajas Dental College & Hospital,
Kavalkinaru Jn,
Tirunelveli District.

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Place: Kavalkinaru **Name: Dr.D.J.Shine Manoj**

Date: **Signature:**

ABSTRACT

TITLE: COMPARATIVE EVALUATION OF STRESS DISTRIBUTION AROUND SINGLE PIECE AND TWO PIECE TITANIUM AND ZIRCONIA IMPLANTS- A THREE DIMENSIONAL FINITE ELEMENT ANALYSIS STUDY- AN INVITRO STUDY

Background: Implants are widely used in the field of dentistry. A material of choice for manufacturing dental implants was for long time commercially pure titanium due to its excellent biocompatibility and mechanical properties. Sometimes grey colour of titanium can give rise to aesthetic problems. Implant researchers had focussed developing tooth coloured implant materials that improves the aesthetic appearance, biocompatibility and ability to withstand the forces generated in the oral cavity. Zirconia based dental implants are the latest high strength materials introduced into the field of implant dentistry. In order to understand the survival and success rate of these implants, stress distribution pattern around the implants is to be assessed. This invitro study was conducted to evaluate the stress distribution around single piece and two piece zirconia and titanium implant using three dimensional finite element analysis.

Materials and methods: Three dimensional finite element analysis models of single piece and two piece titanium and zirconia implants surrounded by cortical and cancellous bone were created using ANSYS software version 10. Stress levels were calculated according to Von Mises criteria. A load of 100N was applied in the cingulum region of maxillary central incisor 2 mm from the incisal edge.

Results: On applying load on single piece titanium showed mean stress value of 4.08 Mpa, two piece titanium showed mean stress value of 4.43 MPa, single piece Zirconia showed stress value of 3.53 Mpa and two piece Zirconia showed stress value around 3.63 Mpa. When all groups were compared statistically to each other there exists no statistically significant difference between single piece titanium & single piece Zirconia and between two piece Zirconia implants & two piece titanium implants. All groups showed equally comparable effects that is stress distribution of Zirconia is equally comparable to titanium

Conclusion: As a conclusion to this study there exist no statistically significant difference in stress distribution between titanium and zirconia, single piece and two piece dental implants. Titanium and Zirconia implants are equally good in distributing stress.

Keywords: Titanium, Zirconia, Finite element analysis, Von Mises stress pattern

LIST OF ABBREVIATIONS USED

(IN ALPHABETICAL ORDER)

ABBREVIATION	WORD EXPLANATION
ANOVA	Analysis Of Variance
FEA	Finite Element Analysis
N	Sample size
p value	Probability Value
SD	Standard Deviation

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INTRODUCTION

The loss of human teeth and the problems concomitant to their successful replacement have plagued mankind for centuries. Following loss of natural teeth, artificial teeth implantation was often attempted with a variety of materials, including carved bone or ivory, various metals, and precious stones. Each year millions of people lose their teeth due to dental caries accidents, diseases and due to aging. [1]

Replacing lost teeth with a bone anchored device is not a new concept. The Mayan civilization has been shown to have used some of the earliest examples of dental implants, dating from about 600 AD. They used shells in the shape of teeth into the sockets of missing three lower incisor teeth. Lots of materials are available currently to be used in dental implantation. In general, this includes, titanium, vitallium, vitreous carbon, ceramics, and polymethyl methacrylate as materials, with endosteal and subperiosteal designs. The endosteal implant relies on medullary bone or support, whereas the sub periosteal implant uses dense cortical bone for support.[1,2]

Bio compatibility of any implant material is of paramount importance. Titanium is generally recognised as the “gold standard” material of endosseous implants. Commercially pure titanium and its alloy demonstrate excellent biocompatibility, corrosion resistance and high mechanical strength, making them the most widely used biomaterials. The biocompatibility of commercially pure titanium stems forms its chemical stability within the organisms, which occurs through the spontaneous formation of a thin, adherent and impermeable passive film of titanium oxide (Tio2) over the surface of materials.[3]

The phenomenon of osseointegration of titanium implants was discovered by a Swedish orthopaedic surgeon, P I BRANEMARK,in 1952,a direct structural and functional connection between ordered living bone and the surface of a load carrying implant. Osseo integration is a direct functional linkage of the implant surface and the surrounding bone mandatorily without any connective tissue.[3,4]

But Titanium implants itself has some drawbacks, like bluish grey appearance of the implant itself and the esthetic ramifications in areas with thin overlying mucosa. Although survival rates of titanium implants are high, peri implantitis and peri implant mucositis around titanium implants are observed. This raises general health concerns and compromises the longevity of the restorations. Corrosion of Titanium alloys in the oral environment and the subsequent release of metal ions and their toxicity is also anticipated.[5]

The elastic modulus and strength of titanium and its alloys are much higher than those human bones which may result in shielding and the failure of implants. Advancement in biomaterial science and ceramic manufacturing technology has allowed production of high strength and biocompatible ceramics that can be used as biomedical devices and implants. The introduction of Yttria –partially Stabilised Tetragonal Zirconia polycrystals (Y-TZP), Powder injection moulding (PIM) and Hot Isotactic Pressing (HIP) techniques were the hallmarks of this development.[6]

Tetragonal zirconia polycrystals (TZP) is characterised by its outstanding mechanical properties, in particular high bending strength and fracture toughness, and a Young’s modulus comparable to that of steel.[7] Compared to other zirconium it is the finest grained, mechanically highest grade, most densely packed structure. It results in extremely high component strength, extra-ordinary bending and tensile strength, fracture and chemical resistance. Oxide ceramics are equal to metals from mechanical standpoint, but biologically stronger. Zirconia implants also proved to be a viable alternative to titanium .Its potential for osseointegration and successful clinical use has been documented.[3]

Zirconia facilitates bone formation when it comes in contact with it and is osseoconductive. Similarly to Titanium osseointegration, the clinical success of Zirconia implants is related to surface properties. CO2 lasers and several complex treatment systems impart to Zirconium, a roughness comparable to that of Titanium implants. Depending on the surface treatment process, bio integration can act chemically or by mechanical irregularities, a determining factor in cell differentiation and maturation. The other advantage of Zirconia materials is its low bacterial adhesion. A significant reduction in pathogenic bacteria has been observed, as well as low plaque adsorption and depolarization, with decreased bone resorption. These are key factors in preserving peri-implant health, and are directly related to restoration longevity. Zirconia based on its biocompatible properties & improved Osseo integration, lesser bacterial adhesion takes importance in new generation of dental implants. From the various in vivo and in vitro studies zirconia seems to be a bio inert material which supports the implementation of this material in dental implantology.[7,8]

However, certain disadvantages are attributed to Zirconia implants, such as higher cost and more limited scientific documentation given for its clinical experience in terms of longevity. Zirconia or “Ceramic Steel” poses outstanding biomechanical properties as a result of the unique transformation toughening mechanism in which transformation of material between different phase's acts as strengthening process to counteract cracks that lead to failure of the material. As a result of this adjunct toughening mechanism, the outstanding mechanical parameters of this material such as flexural strength and fracture toughness exceeding 1200 MPa and 16.0 $Kgf/mm^{2/3}$ respectively, made zirconia feasible to be used as bio-medical implants[7]. The white colour of zirconia is considered as the major advantage over metallic alloys which always have been challenged by the greyish discolouration they might cause to surrounding soft tissues. Introduction of zirconia ceramics with different shades and opacities has also added to the value of zirconia in aesthetically challenging cases.[9]

Colour changes in soft tissues of different thicknesses induced by titanium and zirconia were assessed using spectrophotometry in the experiment by Jung et al who concluded that zirconia induces the least colour changes when compared to titanium even in case of 1.5mm soft tissue thickness. This may indicate that zirconia abutments and implants are theoretically useful in cases of thin gingival biotype and may negate the need for further complicated and potentially morbid soft tissue grafting procedures to augment peri-implant soft tissues in anterior region.[7]

Zirconia dental implants are sensible and clearly a healthier alternative to conventional implants and titanium implant bridges, partial dentures or over dentures. Furthermore Zirconia by virtue of its translucency and all –white colour makes it the most aesthetically pleasing option available today for tooth replacement. This is a new era in implant dentistry and the science of oral implantology.[8]

Different design patterns of the implants are available in the field of dentistry. Different shapes of implants available are hollow screw, hollow cylinder, and angulated hollow cylinder. The four basic thread designs are V-thread, Buttress thread, Reverse buttress thread, Square thread. Thread pitches are coarse pitch and fine pitch.[10] It is found that smaller the thread pitch, lesser the force transmitted to the bone .Implants also comes in one piece and two piece systems each with its own advantages and disadvantages.

One piece implant has a tapered root form with a fixed abutment as an integral part of implant. It has no micro gap between implant and the abutment. But in two piece implants as there is a micro gap, micro leakage and micro movement of the prosthetic abutment can occur and local inflammation of soft tissue around implant may develop. With the elimination of abutment screw, there is no empty space in the implant which provides sufficient strength to one piece implant despite of its smaller diameter compared to two piece implants. It is mainly recommended in narrow dental arches, that is narrow labio lingual ridge.[11,12] Conventional two piece implants require a healing abutment around which soft tissue have to heal, after second stage surgery and they require different prosthetic components, impression coping each different for closed tray or open tray impression techniques and also implant analogue for lab models.

Two piece implants can be used in varying inter arch space. The abutment height and collar length can be adjusted according to the situation and the angulated abutments can be attached to two piece implants. Two piece implants can also be used in screw retained prosthesis. There should be good attached gingiva while using two piece implants. Implants can have either advantageous or destructive effect on the surrounding bone, depending on several physiological, material and mechanical factors. In the light of this, implants should be placed, that transfer occlusal forces to bone within physiologic limits and have geometry capable to enhance bone formation.

For the dental implants to survive in the oral cavity, stress and strain developed around the crestal bone is very important. Highest concentration of stress is observed in the crestal region. The angulation of the implant is one of the most important factor in the management of stress around implants.[13] Bone resorption close to the first thread of osseointergrated implants is frequently observed during initial loading. To achieve stable osseointegration for implant restoration, the generation of high stress concentration in bone should be avoided, since this can induce severe resorption of the surrounding bone, leading to gradual loosening and finally complete loss of implant.[14]

For this stress and strain distributions around different types of dental implants need to be assessed. Several methods based on photo elastic, strain gauge, and finite element analysis (FEA) based studies have been used to investigate stress in the peri-implant region and in the components of implant –supported restorations.

Implant survival rate was based on the fact, that each implant performed its proposed function, and that individual implants or fixed partial dentures were stable when evaluated manually by using the back ends of two instruments. On each side of the prosthesis or implant, to determine the survival, there should not be any movement, absence of pain or infection and the radiographs without indications of pathologic bone loss. With the advancement in implant dentistry, different materials and different structural pattern of implants are available in the field of dentistry. In order to understand the survival and success rate of these implants, the stress distribution pattern around these implants to be assessed. This study evaluates the stress distribution around single piece and two piece titanium and zirconium implants using Three Dimensional Finite Element Analysis.

AIMS & OBJECTIVES

AIM:

The present study was aimed to evaluate the stress distribution around single piece and two piece titanium and zirconia implants using finite element analysis study.

OBJECTIVE:

Primary objective

- To compare the stress distribution around titanium and zirconium implants.

Secondary objective

- To study the stress distribution around one piece and two piece implants.

REVIEW OF LITERATURE

Samuel F.Hulbert etal (1975) [1] conducted a study on the art of dental implants and published materials that could be used in place of missing teeth. The object of this paper is to review many of the numerous materials that are currently being used in dental implantation as well as many of the available designs. In general, this includes ceramics, titanium, Vitallium, vitreous carbon, and poly (methyl methacrylate) as materials with endosteal (direct replica, screw, anchor, and blade) and subperiosteal designs.

Allan M Weinstein etal (1976) [2] conducted a study on porous rooted dental implants by using a Two Dimensional plane stress finite element analysis. The roots of this analysis were compared with results obtained from mechanical tests performed on actual implanted specimen. The appropriate selection of interface material properties was shown to be highly significant.

Kenneth W. M. Judy, etal (1978)[3] the authors recommend that particular attention be paid to this problem in the maxilla in general and in the most posterior aspect of the mandible. Prosthesis and embrasure design should permit complete cleansing and proper gingival stimulation. Patients are informed about the necessity to maintain their percutaneous sites in good health. Routine instruction and evaluation serves to involve patients and transfer responsibility directly to them for their own oral health maintenance.

Alberktsson T etal (1981) [13] conducted a study about Oesseointegrated Titanium implants and evaluated the criteria in an assessment of the long-term efficacy of currently used dental implants including the sub periosteal implants, vitreous carbon implant, the blade vent implant, the single-crystal sapphire implants, the Tubingen implants and the Branemark osseointergrated titanium implants, attempting to standardize the basis for comments on each type of implants.

Inaert etal (1988) [15] conducted a study on overdentures supported by Osseointegrated fixtures for the edentulous mandible: A 2.5-year report, the use of osseointegrated fixtures in combination with an overdenture provides a treatment alternative for functionally and cosmetically restoring the edentulous mandible. Forty-four patients were treated over a period of 2.5 years, and a 97.7% success rate was obtained for the overdentures and the individual loaded fixtures.

Ragnaradell etal (1990) [16] conducted a long term study on osseointergrated implants in the treatment of totally edentulous jaws. This study reviews the long-term outcome of prostheses and fixtures (implants) in 759 totally edentulous jaws of 700 patients. A total of 4,636 standard fixtures were placed and followed according to the osseointegration method for a maximum of 24 years by the original team at the University of Göteborg. Standardized annual clinical and radiographic examinations were conducted as far as possible. A life table approach was applied for statistical analysis.

Patrick J Henry etal (1993)[17] conducted a study on the applicability of osseointegrated implants in the treatment of partially edentulous patients. The complications, failures, and technical problems are presented. After 3 years of this 5-year study, results suggest that implant-based treatment of partially edentulous patients may achieve a success rate comparable to that obtained in edentulous patients.

Dennis C Smith etal(1993)[18] presented a paper about dental implants materials and design and advocated, all the clinician should consider all the available information on the material and design before doing clinical procedures.

Eric P. Holmgren M.S. etal (1998)[19] conducted a study on evaluating parameters of osseointegrated dental implants using FEA to examine the effect of implant diameter variation of press fit, stepped cylindrical implant type and a press fit straight cylindrical type as osseointegrated in the posterior mandible and concluded

- Larger diameter implant is not always the best choice for minimizing cortical bone-implant interface stress.
- Stress is more evenly distributed throughout stepped "cylindrical implant when compared to a straight cylindrical implant.

Barbier C,Vander Sloten J,Krezesinski G, Scheperse, Vander Perre G, ETAL (1998)[20] conducted a study by using Finite Element Analysis study of Non axial versus axial loading oral implants of the mandible in the dog.

Misch Ce etal (1999)[21] conducted a study on mechanical properties of trabecular bone in human mandible implications of dental implant treatment planning and surgical placement and concluded density of bone is directly related to strength of bone.

Hallie E Placko etal (2000) [22] conducted a study on examining the effects of different treatment on surface morphology and chemistry of commercially pure titanium and Ti 6Al 4V by SEM and concluded surface oxides are passively Tio2 on both material for all surface treatments.

Ralph- Joachim Kohal etal (2002)[23] conducted a three dimensional computerized stress analysis of commercially pure titanium and yttrium stabilized zirconia implants. Two three dimensional finite element analysis models of a maxillary incisor with Re-implant implants were made surrounded by cortical and cancellous bone. A porcelain fused to metal crowns for the cpTi implant and a ceramic crown for the YPZS implant were modeled and stress was applied. Result showed higher stresses at the area where the implant entered the bone and stresses were higher at the facial and lingual surfaces than the proximal surface. They finally concluded, stress distribution pattern of Re-implants made of commercially pure titanium and Yttrium - partially Stabilized zirconia implants had very similar stress distribution to CPTi implants and may be a viable esthetic alternative for titanium implant.

Shoichi ishikaki etal (2003)[24] conducted a study on biomechanical stress in bone surrounding an implant under simulated chewing and a natural tooth under chewing function and the result suggested the importance of considering occlusion under chewing function for understanding the biomechanics of oral implants.

Sehinichiro Tadar etal (2003)[14] conducted a study to evaluate the influence of implant design and bone quality on stress /strain distribution in bone around implant using a Three Dimensional Finite Element analysis to evaluate the influence of implant type and length as well as that of bone quality on stress, strain on bone and implant and concluded that cancellous bone of higher rather than lower density might ensure a better biomechanical environment for implants. Longer screw type implants could be a better choice in a jaw with cancellous bone of low density.

Murat CavitCehreli etal (2003) [25] conducted a study on Force transmission of one and two piece morse taper oral implants, nonlinear finite element analysis. They created finite element models of morse taper oral implants and a solid abutments separately. The principal stress distributions around both implants were similar under both loading condition.

Cehreli MC etal(2004)[26] conducted a study on force transmission of one piece and two piece morse taper oral implants – A nonlinear finite element analysis study to compare the force transmission behavior of one piece and two piece morse taper implants and concluded, two piece implants experience higher mechanical stress under oblique loading.

Butz etal (2005)[27] conducted a study on survival rate on fracture strength and failure mode of ceramic implant abutments after chewing stimulation and static loading, and concluded all ceramic abutments made of Al_2O_3 possess less favorable properties like poor capability to withstand tensile stresses due to their inherent brittleness.

Hahn etal (2005)[28] conducted a study on one piece root form implants and concluded one piece implants are superior to two piece dental implants.

Pilathadka S etal (2007)[8] published a review about the properties of zirconia as a new ceramic materials- An overview.

Yuzugullu B etal,(2008)[29] conducted a study on implant abutment interface of alumina and zirconia abutments and concluded zirconia and titanium abutments appeared to demonstrate no statistically significant differences in the measured micro gaps of pre and post loaded assemblies, but titanium abutments developed significant palatal micro gap after cyclic loading. Differences in machining tolerances exist between implant components. Higher degree of forces are expected to be applied to labial and palatal surfaces in function due to the angle of loading and in the current study this resulted a significant difference in the palatal micro gap of titanium abutments.

Sergio E T Quaresma etal, (2008)[5] did a finite element analysis of two different dental implants: stress distribution in the prosthesis, abutment, implant and supporting bone, under occlusal forces. The implants and abutments evaluated consisted of a stepped cylinder implant connected to a screw-retained, internal ,hexagonal abutment system and a conical implant connected to a solid ,internal conical abutment system .A porcelain covered ,silver palladium alloy was used as a crown .A simulated 100 N load was applied to the buccal cusp. A Finite element analysis was created based on the physical properties of each component and the values of the von Mises stresses generated in the prosthesis, abutment, implant and supporting alveolar bone were calculated. Within the limits of the investigation ,the stepped cylinder implant connected to a screw –retained ,internal hexagonal abutment produces greater stresses on the alveolar bone and prosthesis and lower stresses on the abutment complex .In contrast, conical implant connected to a solid, internal, conical abutment furnishes lower stresses on the alveolar bone and prosthesis and greater stresses on the abutment.

Ralf –j- kohal etal (2008) [30] conducted a study on ceramic abutment and ceramic oral implants and concluded yttrium stabilized Zirconia implants had similar stress distribution to commercially pure titanium implants. Dental implants are considered an essential treatment modality. Dental implants and abutments are usually fabricated out of pure titanium, because of its well documented biocompatibility and mechanical properties. Titanium implants had disadvantage of metallic components showing through. To achieve optimal esthetics, ceramic abutments and implants were developed.

Luigi. Bagg etal (2008)[31] conducted a study on influence of implant diameter and length on stress distribution of osseointegrated implants related to crestal geometry by using finite element analysis and concluded, that within limitation of study, Load transfer mechanisms and possible failure of osseointegrated implants are affected by implant shape, geometrical and mechanical properties of the site of placement, as well as the crestal bone resorption. Suitable estimation of such effects allows for correct design of implant features. Maximum stresses were numerically located at the implant neck, and possible overloading could occur in compression in compact bone due to lateral components of occlusal load and in tension at the interface between cortical and trabecular bone due to vertical intrusive loading components. Stress values and concentration areas decreased for cortical bone when implant diameter increased, whereas more effective stress distributions for cancellous bone were experienced with increasing implant length. Dissimilar stress-based performances were exhibited for mandibular and maxillary placements, resulting in higher compressive stress in maxillary situations.

Inaki Gamborena etal (2008)[32]**,**conducted a study on clinical and technical protocols for single tooth immediate implant procedures, and concluded immediate surgical and restorative protocols facilitate superior esthetic and functional success. An immediate implant provides additional benefits to the patients in terms of appearance and overall length of the treatment. Implants made of zirconium oxide provide sufficient strength, excellent biologic response and superior esthetic properties. However strict guidelines for a traumatic intervention and preservation of existing anatomic structures must be carefully followed.

Hanz J. Wenz, etal (2008)[33] conducted a study on osseointegration and success of zirconia implants by doing animal studies. Osseointegration was evaluated at 4weeks to 24 months after placing in different animal models and sites and under different loading conditions. The mean implant –bone contact percentage was above 69% in almost all experimental groups and concluded osseointegration of Y- Tzp (yttria- Stabilised Tetragonal Zirconia poly crystals) implants might be comparable to that of Titanium implants. Y-tzp implants may have the potential to become an alternative to titanium implants.

Wolf hart Rieger etal (2008)[34] conducted a study on processing and properties of zirconia ceramics for dental applications, described the characteristics of so called tetragonal zirconia poly crystals and concluded, there are no uncontrollable risk or long term deficiencies to be expected in the area of dentistry associated with use of high quality TZP ceramics.

Sergio ET Quaresma etal (2008)[35] conducted a study to evaluate the influence of two commercially available dental implant systems on stress distribution in prosthesis, abutment, implants and alveolar bone under simulated occlusal force, employing a FEA study. Within limits of investigation, stepped cylinder implant cemented to screw retained, internal hexagonal abutment produces greater stresses on alveolar bone and prosthesis and lower stresses on abutment complex.

F.P Koch etal(2009)[36] conducted a study of one piece zirconia implants compared with a titanium implant of identical design- histomorphic study in the dog to evaluate osseointegration of one piece zirconia and one piece titanium implants depending on their insertion depth by histo-morphometry and concluded that zirconia implants are capable of establishing close bone to implant contact rats similar to what is known from the osseointegration behavior of titanium implants with the same surface modification and roughness.

PA Stone etal(2009)[37] conducted a study on bone implant material and concluded implant material influence the mechanical properties of implant as well on the bio compatibility in terms of contact with the bone and soft tissue.

Guilherme Carvalho Silva etal (2010)[38] conducted a study on stress pattern on implant in prosthesis supported by 4 or 6 implants using a Three Dimensional Finite Element Analysis and compared the biomechanical behavior of All on Four systems with that of six implants supported maxillary prosthesis with tilted distal implants. The Von Mises stress induced on the implants under different loading simulations were localized and quantified. The stress location and distribution patterns were similar in two models. The addition of implants resulted in a reduction of Von Mises stress values. The cantilever greatly increased the stress.

Erika Oliveira de Almeida etal (2010)[39] conducted a study to evaluate the influence of different type of bone on the stress distribution in mandibular bone supporting a prefabricated bar type implant prosthesis using a Three Dimensional Finite Element analysis and concluded cortical bone in type 3 and type 4 bone showed the highest stress concentration in axial and bucco- lingual loading, and the cortical bone in M4 showed maximum stress concentration and type 1 and 2 showed less stress in bone.

Wan – ling shen etal (2010)[40] conducted a study on influence of implant collar design on stress and strain distribution in the crestal compact bone by using a three Dimensional Finite Element Analysis to evaluate the influence of implant collar geometry on the distribution of stress and strain in the crestal compact bone and concluded ,stress and strain distribution in the adjacent crestal compact bone were influenced by implant collar design, and divergent implant collar design demonstrated the lowest stress strain concentration in contiguous crestal compact bone.

Guilherm ecarvalho Silva etal (2010)(41) conducted a study on stress pattern on implants in prosthesis supported by four or six implants using a Three Dimensional Finite Element Analysis, compared the biomechanical behavior of all on four with six implanted supported maxillary prosthesis and concluded, addition of cantilever will greatly increase stress on the dental implants, regardless of whether or not the prostheses is supported by four or six implants.

Sailer etal (2010)(42) conducted a study on systemic review of performance of ceramic and metal implants abutments supporting fixed implants reconstructions and concluded annual failure\ rates for Ceramic and metal abutment are similar.

Saied Nokar etal (2011)(43) conducted a study on the effect of super structure designs on stress distribution in peri implant bone during mandibular flexure by using Finite Element Analysis and concluded, mandibular deformations was an important factor in stress distribution and it should be considered in the design of implant supported fixed partial denture in mandible.

Alper Cagler etal (2011)(44) conducted a study on Three dimensional Finite Element Analysis of Titanium and Yttrium –Stabilized Zirconium Dioxide abutments and implants, to compare the von Mises (vM),compressive, and tensile stresses occurring on three different zirconia dental implants Z-system, Ziterion, White sky dental implants, abutments and surrounding bone ,in anterior ,maxillary region a single titanium implants with titanium abutments, single titanium with zirconium abutments and single one piece zirconium and concluded zirconia implants developed lesser stress. The difference in stress value may be due to diferent body and thread designs of the implants.

Kyung- Ho Yoon etal (2011)(45) conducted a FEA study on changes in stress levels and stress distribution for an osseointegrated implant after vertical bone loss and concluded higher bone levels has a bio-mechanical advantage with respect to stress concentration. This study was done to study the effect of stress level and distribution around non submerged implants and vertical bone resorption was evaluated.

Alper canglar etal (2011)(46) conducted a study on titanium and yttrium stabilized zirconium dioxide abutments and implants to compare the Von Mises stress, compressive and tensile stresses occurring on implants, abutments, and surrounding bone using Three Dimensional Finite Element Analysis in anterior maxilla using a single titanium implant with abutment a single titanium implant with zirconia abutment and single one piece zirconia implant and concluded, yttrium stabilized zirconia implants transmitted lower stress values than Astra- Tech titanium implant in cortical and trabecular bone.

Myron Nevins etal (2011)(47) conducted a pilot study on clinical and histological evaluation of two piece zirconia implants and concluded, finding of human biopsied two-piece Zirconia implant demonstrated maintenance of crestal bone level and provided clinical and histological evidence of Osseo integration.

Bal B. etal, (2011)[48] conducted a study by splinting implants, and concluded when implant were splinted together, stresses were reduced in the supporting bone and implants in loading condition. Zirconium and Titanium implants showed similar stress distributions in all materials.

Chirag J. Chauhan etal (2011)[9] conducted a study on evaluation of biomaterials in implants and concluded appropriate selection of biomaterial directly influences, clinical success and longevity of implant. Recent bio-ceramics and composite bio materials have promising future. These articles summarize the properties of different implant biomaterials available in the market.

Stephen Barter etal,(2012)[4] conducted a pilot study to evaluate the success and survival rate of titanium and zirconium implants on partially edentulous arches and after two year follow up, a newly developed Titanium zirconium alloy in combination with SL Active surface is a suitable materials for small diameter implants.

Bobin, Slauja etal (2012)[6] did a study on effect of length ,diameter on stress distribution pattern on INDIDENT dental implants by FEA to study the influence of stress on varying length and diameter of implants, and concluded that in type – IV bone, implant length is more crucial in reducing bone stress and enhancing the stability of implant abutment complex than implants.

Ahmad. A Jumah etal (2012)[7] did a study on zirconia implant and concluded, Zirconia dental implant may be considered as a new approach to optimize esthetic outcome of immediate replacement technique in the esthetic zone.

Chih- Ling Chang etal (2012)[11] did a three dimensional finite element analysis study to evaluate biomechanical effect of zirconia implants using crown system and concluded, maximum von mises stress and compressive stress in compact bone between two different interfaces were lower in zirconia implant model than in titanium implant model. Zirconia may be a viable alternative especially for esthetic region.

Zeev Ormainer DMD etal (2012)[49] conducted a study on stress and strain patterns of one piece and two piece implant systems in bone, A Three Dimensional Finite Element Analysis and concluded implant diameter and peri implant bone thickness influence the load distribution in bone, but the type of implant abutment transition had no significant effect. One piece implant should be connected to dense bone to minimize stress concentration.

PrithViraj etal (2012),[50] did a systemic review on zirconia implants and found zirconia implants, shows good peri-implant result, to suggest good biocompatibility of zirconia implants with surrounding tissue, no bacterial accumulation, good osseointegration and esthetics with zirconia implants.

Alper.gultekin etal(2012)[51] who did a study on FEA in implant dentistry and said FEA is a numerical stress analysis technique and is extensively used in implant density to evaluate the risk factor from a bio mechanical point of view correlating FEA results with pre-clinical & long term clinical studies may help to validate research models.

Ali Balik etal (2012) [52] conducted a study on effect of different abutment connection design on stress distribution around five different implants using Three Dimensional Finite Element Analysis to evaluate five different implant abutment connection design from five different manufacturers and concluded conical plus internal hexagonal and screw in implant abutment connection is more successful than other systems especially in posterior regions.

Saluja BI etal (2012)(53) published a review about one piece implant and suggested the advantage and disadvantage of one piece implant over two piece implants.

Manmohan Choudary etal(2013)(54) conducted a study on predicting peri implant structures around titanium implants and zirconium implants using finite element analysis and concluded zirconium implants led to lower peri implant stresses than titanium implants.

Eitan Mijiritsky etal(2013)(55) conducted a study to compare the implant diameter and strength influence on survival and in the first two years of function, less than 10mm implants and narrow less than 3.75 mm implants could be successfully placed in partially edentulous patients.

Guilherme Carvalho Silva etal(2013)(56) conducted a method for obtaining a three dimensional geometric implants using FEA and saw, creation of precise geometric model by means of appropriate engineering software in essential for obtaining reliable and realistic solutions.

Jae M Barrachin Diez etal (2013)(57) conducted a study on long term outcome of one piece implants – A systemic literature review with meta-analysis to evaluate, the long term clinical performance of prosthetic reconstruction on one piece implants with forces on technical and biological complication. Within the limits of the study, it can be concluded that despite long term prosthetic survival rate, technical and biological complication are frequent in one piece implants.

Samir Anand etal(2013)[58] conducted a study on Bone platform switching and concluded, inward horizontal repositioning of implant abutment interface away from the crestal bone into a more confined area has positively influenced bone resorption by using Alpha-Bio SFB implants.

Wagner Moreisa etal (2013) [59] conducted a three dimensional finite element analysis study on stress distribution pattern of two prosthetic abutments for external hexagon implants, to evaluate the mechanical behaviour of two different prosthetic abutments for external hex butt-joint. One model was designed for two piece prosthetic abutment with their corresponding screws and implants and another for one piece abutment with their corresponding screws and implants. The model simulated the single restoration of a lower premolar using data from computed tomography of a mandible. Preload (20N) after torque application of the abutment and an occlusal loading were simulated. The region with highest von Mises stress results were at the bottom of the initial two threads of both the prosthetic abutments that were tested. The one-piece prosthetic abutment presented a more homogenous behavior of stress distribution when compared with the two piece abutment.

Chiung- Fangwang etal (2013)[60] conducted a study on comparison of maximum deformation and failure force at abutment intra face of titanium implants between titanium alloy and zirconium abutments with two levels of marginal bone loss and concluded, implant with a stimulated marginal bone loss of 3mm exhibited decreased maximum deformation and failure forces compared to those with a simulated marginal bone loss of 1.5 mm zirconia abutments can with stand psychological occlusal forces applied in anterior region for both 1.5 mm and 3 mm marginal bone loss and clinical use of zirconia abutment should be considered when esthetic outcomes are important.

Lih-jyh fuh etal (2013)[61] conducted a Three Dimensional Finite element analysis study on biomechanical investigation of thread designs and interface conditions of zirconia and titanium dental implants with bone and evaluated bone stress and interfacial sliding at the bone implant interface and concluded zirconia implants can reduce the bone stress.

Kishor kumar G. Khandane etal (2013)[62] conducted a finite element analysis study for stress analogue zirconia Dental implant and concluded, favourable mechanical biological esthetic properties potential osseointegration and the ability to customize it and place it immediately following extraction make zirconia, a material of choice for dental implant in recent times.

Nicollo Mobilio etal (2013) [63] conducted a study on one piece titanium and zirconium implants to know the stress developed and concluded, stresses developed around the two implants are very similar.

Lih-j Jyh Fuh etal (2013) [64] conducted a biomechanical investigation of thread designs and interface conditions of zirconia and titanium dental implants with bone: A three Dimensional Numeric Analysis, on bone stress and interfacial sliding at the bone implant interface were analyzed in zirconia and titanium implants with various thread designs and interface conditions for both conventional and immediately loaded implants. They concluded as an implant material, zirconia implant material can reduce bone stress in crestal region. Bone stress and sliding at the bone implant interface are heavily dependent on the thread design and the frictional coefficient at the bone implant interface of immediately loaded implants.

Felix Brull etal (2014)[65] conducted a clinical radiographic and microbiologic evaluation of Zirconia Dental Implants, by treating seventy our consecutively treated patients with 121 zirconia implants and clinically evaluated after a period of 18 months. He concluded that zirconia endosseous implants can achieve a 3 year survival rate in partially edentulous patients, similar to that of titanium implants, with healthy and stable soft and hard tissues.

Vishnu Rajendran etal(2014)[66] conducted a study on stress analysis of dental implants ,by using a finite element analysis study on implant and surrounding bone structure after obtaining 100% osseointegration, and concluded that the area with the highest stress to be around the dental implant at the cervical margin.

Sikha Nandal etal (2014)[67] published a comprehensive review literature on osseointegration of dental implants saying osseointegration of dental implants refers to the process bone growing right up to the implant surface without any soft tissue between bone to the surface of dental implants . There is a direct contact of bone and implant surface that could be viewed microscopically.

Kamble Vikas B etal (2014) [12] published a review of literature which outlines the indications, advantages, disadvantages, surgical protocols and prosthetic phase of one piece implants.

MATERIALS AND METHODS

To study the stress distribution around single piece and two piece titanium and zirconium implants, A THREE DIMENSIONAL FINITE ELEMENT ANALYSIS was planned. A three dimensional finite element analysis study was undertaken to model and analyze the stress concentration in loaded situation. FEA was chosen for this study as it is useful in determining the stress and strain around the dental implants. FEA is a numerical stress analysis technique that is widely used to assess engineering and biomechanical problems before they occur. A finite element model is created by dividing solid objects into several elements that are connected at a common nodal point. Each element is assigned to be with appropriate material properties corresponding to the properties of the object being modeled.

The first step is to subdivide the complex object geometry into smaller elements of finite dimensions. When combined with the mesh model of the investigated structures, each element can adopt a specific geometric shape (triangular, square, tetrahedron) with a specific internal strain function. Using these functions and the actual geometry of the element, the equilibrium equations between the external forces acting on the element and the displacement occurring at each node can be determined. FEA allows application of simulated forces at specific points in the system and stress analysis in the peri-implant region and surrounding structures.

BASIC CONCEPT OF FINITE ELEMENT ANALYSIS:

The finite element method is an approximate numerical method of stress analysis, used in solving complex structural problems by dividing the complex structures into simpler and smaller segments. A computer simulated model is analyzed to a numerical and graphical solution. In the finite element method the actual continuum or the complex structures is divided into smaller subdivisions called elements. The elements are interconnected at specific joints called nodes. The whole collection of elements and nodes is called a mesh. With the incorporation of mechanical properties, the structure simulates the normal model.

The nodes lie on the element boundaries where adjacent elements are connected. Since the actual field variables (displacement, stress,) inside the continuum are unknown, it is approximated by simple function. These approximating functions (interpolation nodes) are defined in terms of the values of field variables at the nodes. By solving the field equations, which are generally in the form of matrix equations, the nodal values of the field are known and hence the result is numerical and graphical.

The finite element method has some distinct advantages over the other methods of stress analysis:[66]

- ❖ The technique is non-invasive.
- ❖ The tooth, the alveolar bone, implant can be simulated and when the material properties of these structures are assigned, it is the nearest that one can possibly get in simulating the oral environment in-vitro.
- ❖ The actual stress experienced at any point can be measured.
- ❖ The actual displacement of the implant can be visualized graphically.
- ❖ Reproducibility does not affect physical properties of the involved material and the study can be repeated any number of times.

- The finite element method has a potential for accurate modeling of real object of complicated shape and different material properties.

There are several Finite element analysis packages like Ansys, Cosmos, Nastran, but for systems of large difference in material properties and stiffness, Ansys will be suitable software. There are two different modules of Ansys, the Classical and Workbench. Classical is very good and old version but translation errors are large in this module. Ansys workbench is a recent version of Ansys which can import models with 100% data transfer or with 0% data loss. Once imported, the software can do an automatic meshing with defined material properties. The software establishes contacts automatically and defines them as bonded contact. This is of very great use as we need not spend time in selecting surfaces to design contacts. This comes to a great use especially when there are lots of components between which contact need to be defined.

Meshing divides the entire model into smaller elements. The model was subdivided into 50,000 nodes and 35,000 elements. Once meshing and contacts are defined the next process is to define boundary conditions. After defining the Boundary of the model the loads to be applied are defined. Once the loads are defined, then the problem is solved by incorporation of material properties and the results can be reviewed.

MODELIZATION OF LIVING STRUCTURE:-

BONE MODEL:

To improve the quality of FEA research, strict attention should be paid to the modelization procedure as one of the most important part of FEA studies. The features of the model should resemble the physical properties of the actual structures as closely as possible, with respect to dimension and material properties. The most difficult and complex part of the modelization process involves capturing the detailed properties of living structures. Therefore in general, specifications drawn from chapters of detailed anatomy book, from tomographic scans of a jaw or from cadaveric human specimen can be used for the modeling procedure. Volumetric data obtained from tomography device or magnetic resonance imagings are digitally constructed. Then the material properties applied to the elements can be varied according to the modeling requirements of a particular situation.

Computed tomography offers another advantage for realistic modeling in not only the development of anatomical structure, but also inclusion of different bone density values. In some detailed studies, the bone is totally or partially modeled in a very realistic manner. According to treatment alternatives, there is no need to visualize and construct a model of entire jaw. A region of interest can be extracted using a number of techniques, such as Boolean process, and any implant design can be used for the study. Region of interest may change according to the study protocol. Portions of mandible or maxilla, maxillary sinus region, are the most common anatomical areas used in studies related to implantology. Maxillary bone was modeled as a section of bone approximately the frontal part of maxilla, with cortical bone thickness of 1.5 mm enclosing a trabecular bone core.

Properties approximating those D3 bone were used. (D3 bone 350 -850 hounse field units). Woven Bone of 1.5 mm thickness was modeled around the implants with a bone implant contact of 65% to stimulate the immediately loaded situation. Bone block was modeled to be 15mm length and buccolingually 10mm wide to incorporate the implant dimension in it.

MODIFICATION OF NON-LIVING STRUCTURES (MATERIALS):

Non –living mechanical structure such as implants, abutments, and restorations can be simulated in detail and can substantially influence the calculated stress strain values, similar to living structures.

These materials can be modeled digitally in FEA studies, is determined to be with transversely isotropic properties. In isotropic material, the relevant material properties are the same in all directions, resulting in only two independent material constants. Young’s modulus expressed in (Mpa) also known as tensile modulus is a quantity used to characterize material and is a measure of stiffness of an elastic material.

IMPLANT MODEL:

Implant used- Denti Systems was founded in 1989, Hungary (Budapest). DENTI systems is certified by the MZN EN ISO 13485:2004 and MSZ EN ISO 9001:2001 quality management standards.

DENTI IMPLANTS MADE OF UN ALLOYED PURE TITANIUM AS

- Two stage root form implant (DR)
- One stage root form conical screw form implants(DOP)

DENTI IMPLANTS MADE OF ZIRCONIUM DIOXIDE

- Two stage root form implants (DentiCircon Root/DCR)
- One stage root form (conical screw implant/Denticirconium/DC)

DCR and DC implants are made of zirconium dioxide stabilized with yttrium. High purity zirconium is a bio inert oxide ceramic. Its material –mechanical properties are stabilized with the addition of yttrium dioxide which has a beneficial effect on the mechanical properties. An important property of zirconium dioxide is that up to a certain load limit it can stop micro cracks in a self –healing way.

OTHER PROPERTIES:

i. Bio-compatible, Bio-inert as an alternative to titanium
ii. Color similar to that of natural tooth
iii. High flexural strength and firmness-abrasion resistant
iv. Poor electrical and thermal conductor
v. Low surface potential– low plaque accumulation.

Solid tapered implants of 11.5 mm length, and diameter 3.8mm, is modeled and simulated to be placed in the section of bone. Straight abutments with diameters 3.8mm and length 10mm is used. Three dimensional tetrahedral structural models of the implant, bone and abutments have been fabricated using pro engineer wildfire 4 software. All materials used in the models were considered to be isotropic homogenous and linearly elastic.

IMPLANT SIZE:

One piece titanium implant------ length 19mm, width 3.8 mm

One piece zirconia implant ------- length 19mm, width 3.8mm

Two piece titanium implant ------ length 11.5 mm, width 3.8 mm

Two piece zirconium implant ---- length 11.5 mm, width 3.8mm

ABUTMENT:

- Screw retained
- Cemented

FIXING SCREW:-

CROWNS:

All ceramic crowns made of zirconium.

MATERIAL PROPERTIES:-

ELASTIC MODULUS:

It is the mechanical property that determines the load deflection rate of a material

Table.No:01- Modulus of elasticity of the materials used

Materials	Elastic Modulus
Cortical bone	13.5-15.5 Mpa
Cancellous bone	6 Mpa
Titanium alloy	113.8Mpa
Zirconia implant and abutment	200Mpa

LOAD:

Axial load were applied. Since average masticatory force ranges from (100-300N), load value of 100N was used in this study.

SOFTWARE USED:

FEA of the implant models were carried out using ANSYS WORK BENCH 10 SOFTWARE.

NUMBER OF NODES AND ELEMENTS USED:

Number of nodes and elements used in this study were approximately, 50,000& 35,000 respectively. On stressing with axial load of 100N, the tensile stress, compressive stress and the micro strain values around the implants in the crestal bone are recorded. The micro strain values obtained around single piece implants and two piece implants were compared and evaluated to see whether they are within an ideal range.

MODELLING:

The first step involved is modeling. The modeling was done using software called pro/engineer. The Pro/engineer is a three dimensional software which is a product of PARAMETRIC TECHNOLOGY CORPORATION. The software is among the very reliable and old parametric modeling package. Using the software, models can be made in very short time , editing of the models can be done with great ease, surfaces can be created and controlled to get exact shapes at microscopic levels.

As an implant is complex in shape, for creating a model the computer tomography scan data is required. The implant is scanned at various sections at regular intervals of 0.5mm. These scanned images are then imported into Pro/E software to various offset planes. Then manually in different sketch planes the curves are created along the implant to get the exact shape. Once the curve is created then lateral curves are created to have proper surface smoothness flow, to ensure proper surface lateral connectivity. This will help to get rid of wrinkles on the surfaces. Wrinkles on surface will greatly affect fem model and can result in wrong results.

From the curves, surfaces are created using a command called Boundaries. For this command the surface creation requires curves in the form of mesh that is curves in two directions, set of linear curves and a set of lateral curves need to be selected in order. From the surfaces, solid is generated. Once the implant is developed in similar fashion, other parts are created and assembled. This assembly is then exported to an analysis package which is a bidirectional understandable translator called IGES. The export is through a bidirectional understandable translator called IGES. This file format of export is understandable by most of the software

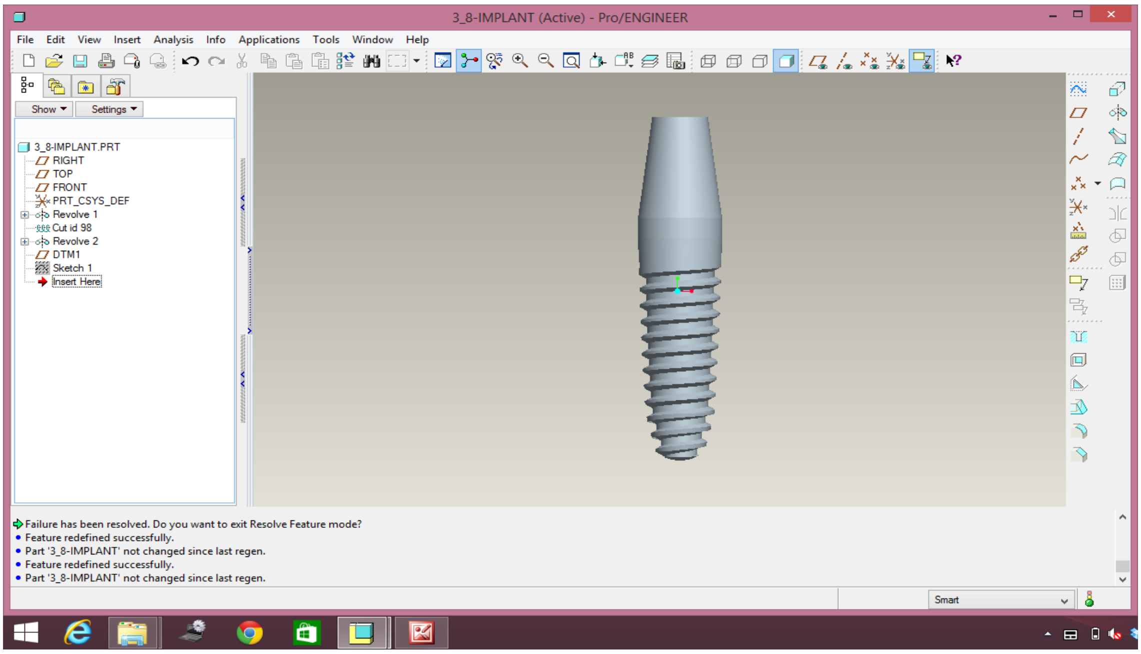


Fig: 01- Single piece titanium implant

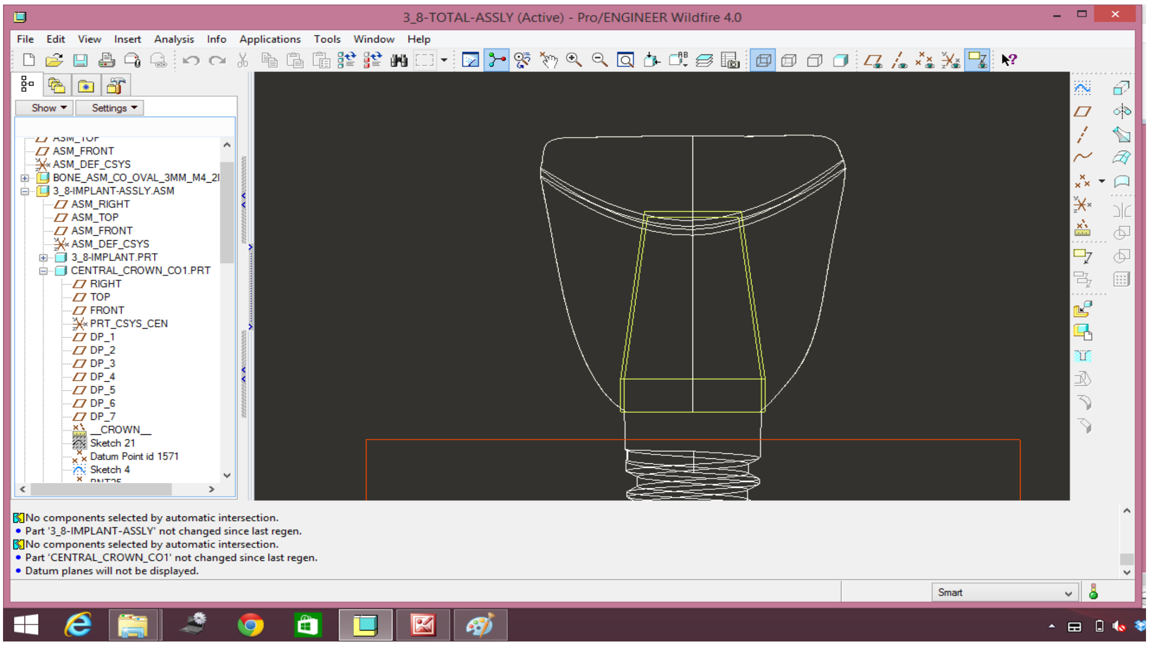


Fig: 02- Cross sectional view of single piece titanium implant

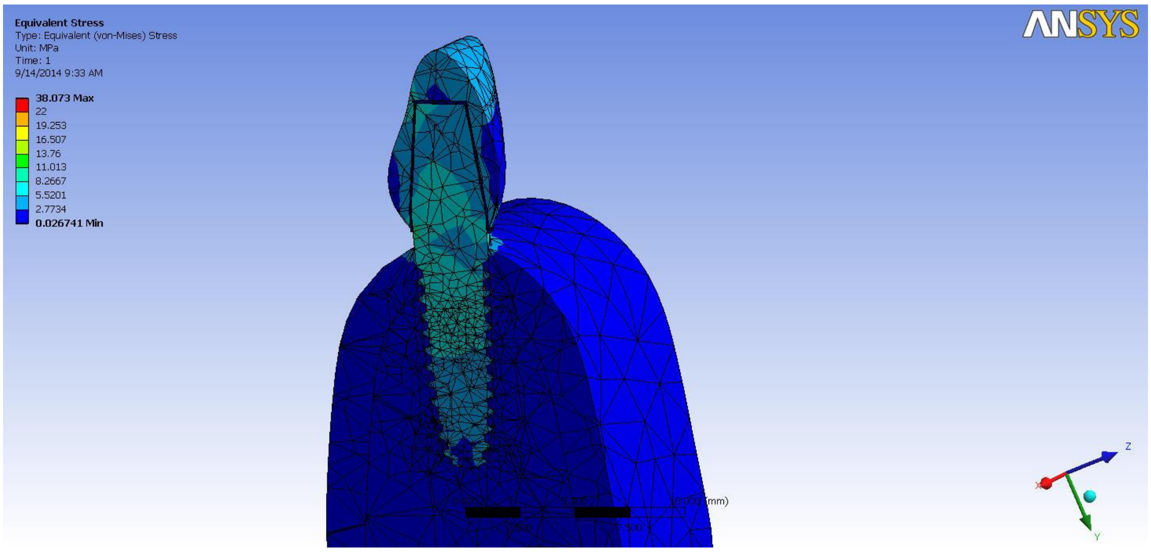


Fig :03- Mesh model for single piece titanium implant

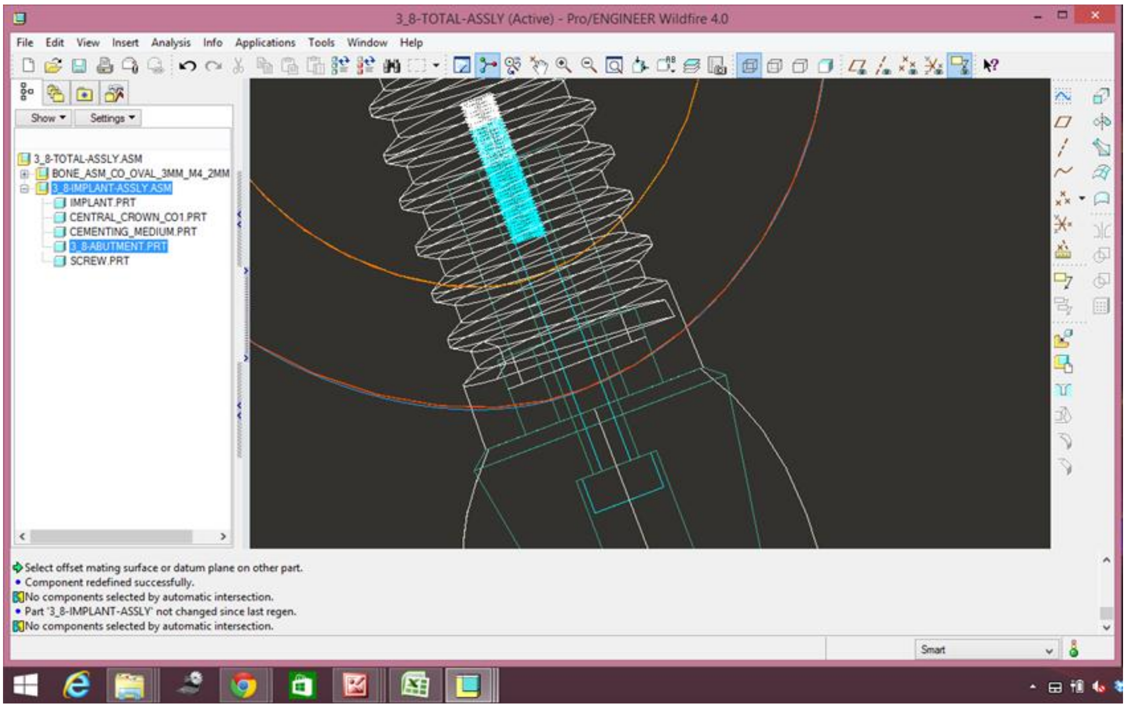


Fig: 04- Cross sectional view of two piece titanium implants

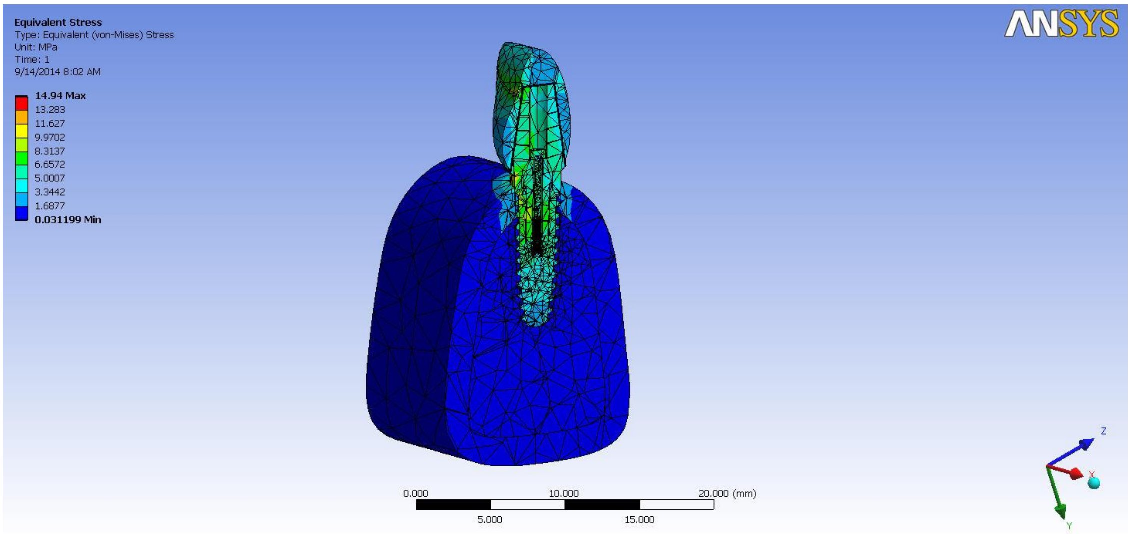


Fig: 05- Mesh model created for two piece titanium implant

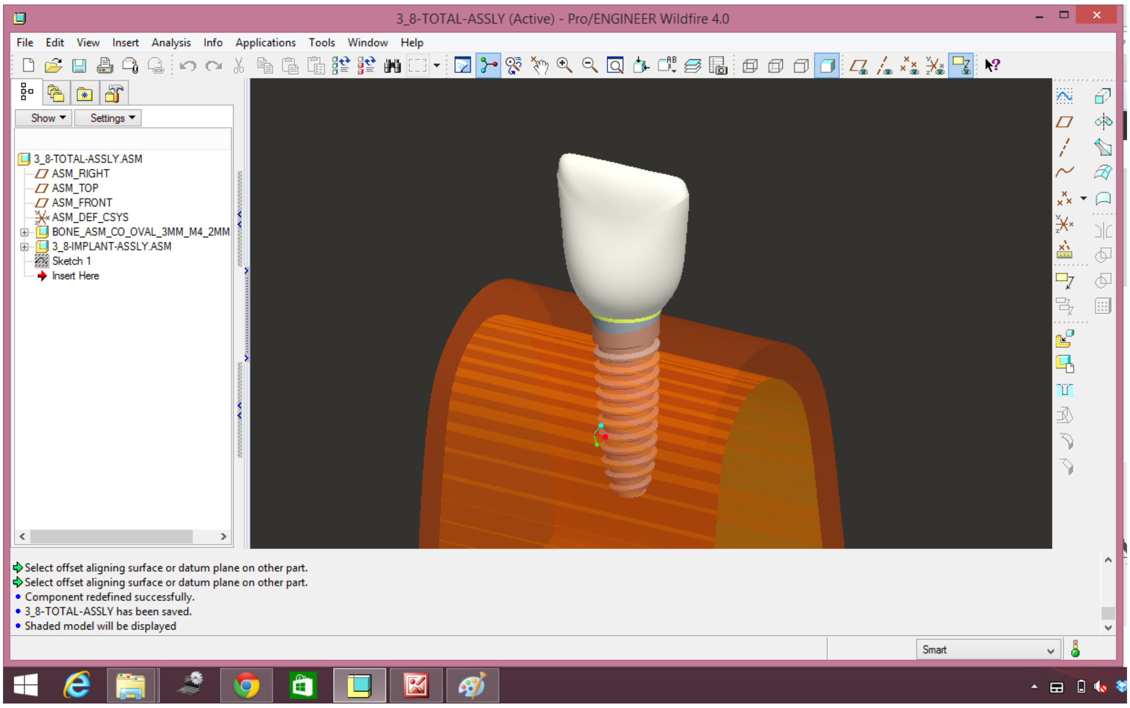


FIG: 06- Single piece zirconia implant

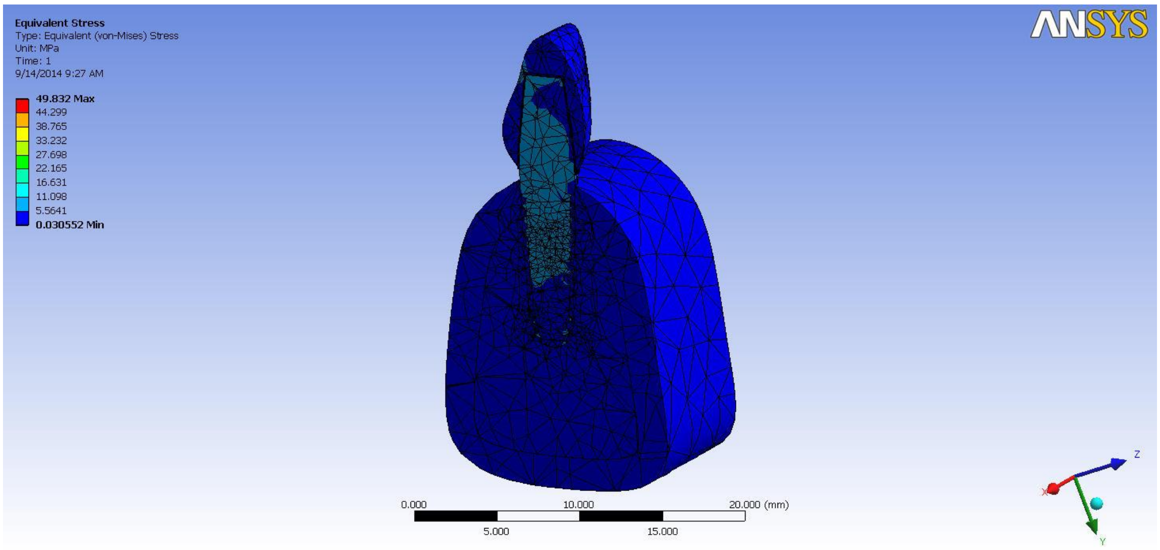


Fig: 07- Mesh model for single piece Zirconia implant

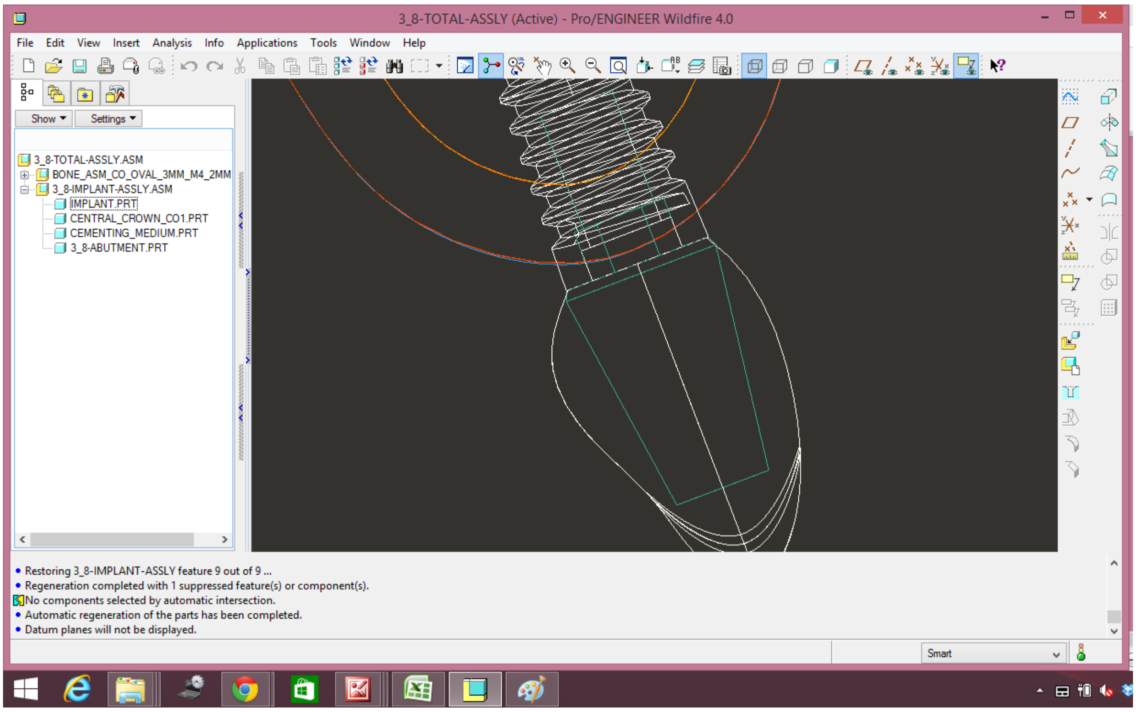


Fig: 08- Cross- sectional view of two piece zirconia implant

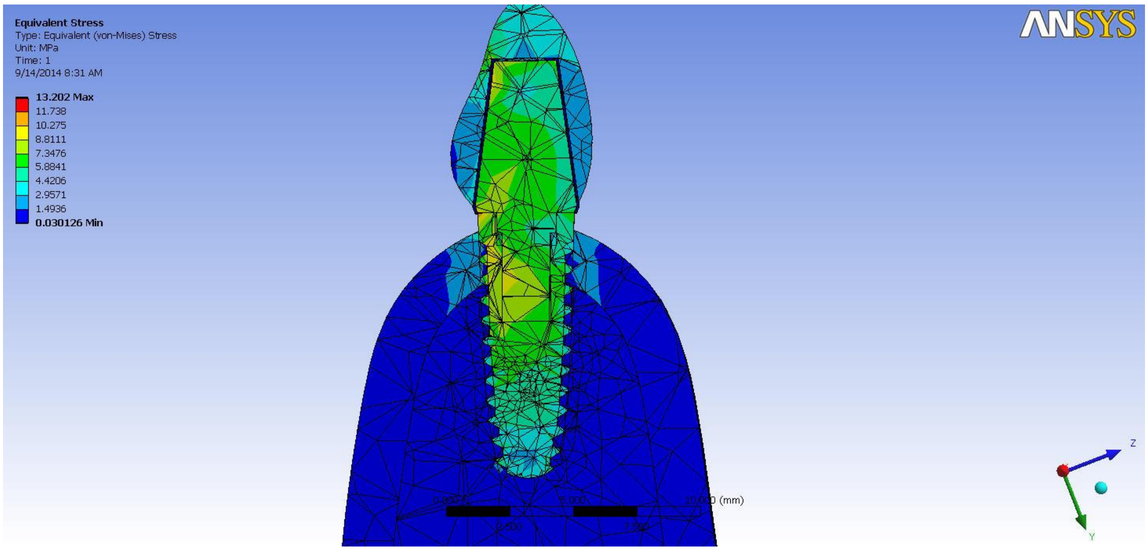


Fig: 09 – Mesh model for two piece Zirconia implants

RESULTS

The present in-vitro study was done to compare and evaluate the stress distribution around single piece and two piece titanium and zirconia implants, using finite element analysis. A load of 100N was applied 2mm from incisal edge of maxillary central incisor.

The colour plots obtained were studied and maximum Von Mises stress and a strain were noted and tabulated for each condition. The unit of stress is the unit of force (N) divided by a unit area or length squared and is commonly expressed as Pascal (Anusavice, skinners science of dental materials), publication Unit “Megapascals”- MPa.

Stress distribution in the FE models comes in numerical values and in colour coding. Maximum values of Von Mises are denoted by red colour and minimum value by blue colour. In between values are represented by bluish green, greenish yellow and yellowish red in the ascending order of stress distribution. Stress distribution around single piece titanium implants, two piece titanium implants, single piece zirconium implants and two piece zirconia implants are shown in fig:10,fig:11, fig:12, fig:13, fig:14, fig:15, fig:16 and fig:17 under oblique loading.

Statistical analysis was done and the data’s were expressed in MPa. Statistical package for social sciences (SPSS 16.0) version was used for statistical analysis. One way ANOVA test was applied for analysis. Post Hoc followed Dunnet t test was used to find statistical significance between groups and within the groups. P value less than 0.005 ($P<0.05$) was considered statistically significant at 95% confidence interval. **Mean stress value Results of different groups of materials are given in Table -02.**

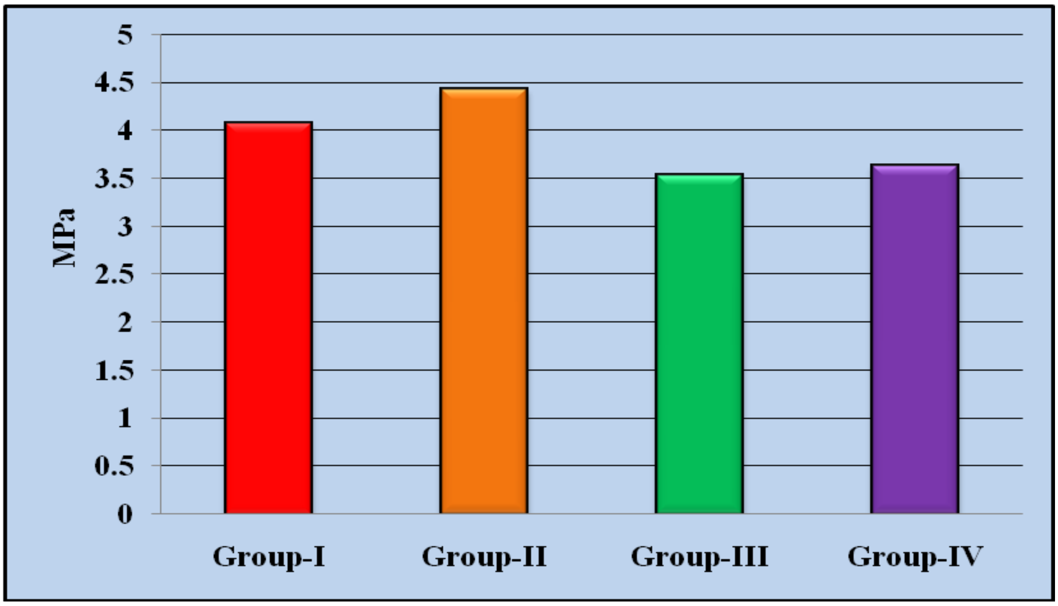
- Single piece titanium implant showed 4.08±0.94 MPa stress. It was compared with other groups. The comparison showed statistically insignificant difference.
- Two piece titanium showed 4.43±1.33 MPa stress. Its comparison with other groups showed p-value more than 0.05.It was statistically insignificant.
- Single piece Zirconia showed 3.53±1.36 MPa stress. Comparison of single piece Zirconia with other group showed no statistical significance with p value more than 0.05.
- Two piece Zirconia showed 3.63±0.78. The comparison of mean stress value with other groups showed insignificant results.
- Single piece titanium showed less stress compared to two piece titanium. The difference between the two groups showed no statistically significant difference.
- Single piece Zirconia showed less stress than two piece Zirconia. The difference between the groups showed no statistically significant difference.
- Single piece titanium and two piece titanium showed statistically insignificant difference compared to single piece Zirconia and two piece Zirconia.

Table: 02- Mean maximum stress (MPa) values of different groups of materials

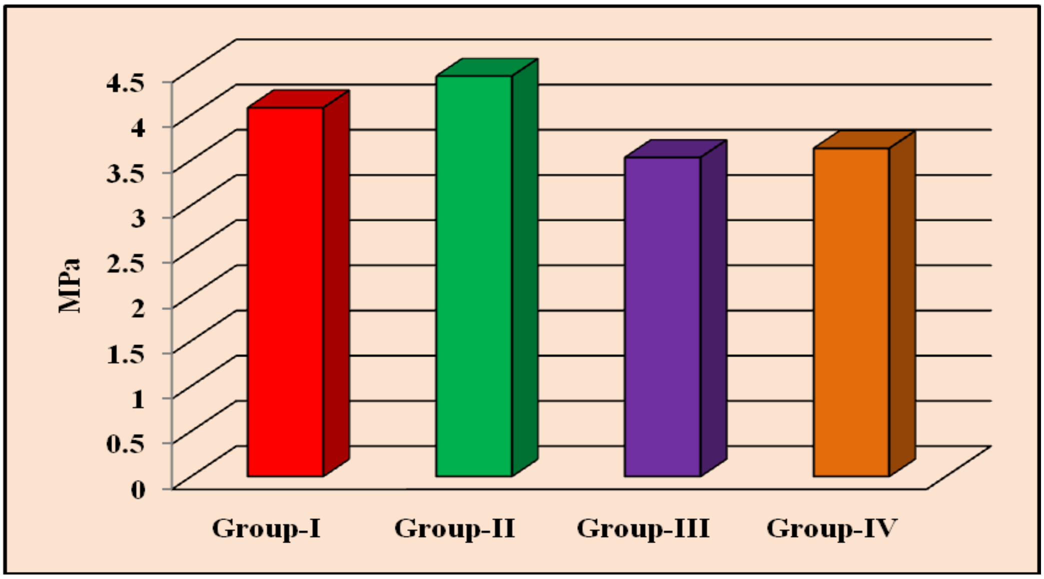
Groups	Type of material	Maximum stress (MPa) (MEAN±SD)
Group-I	Single Piece Titanium	4.08±0.94
Group-II	Two Piece Titanium	4.43±1.33
Group-III	Single Piece Zirconia	3.53±1.36
Group-IV	Two Piece Zirconia	3.63±0.78

Table: 03- Multiple comparison of mean maximum stress (MPa) values between the groups of materials

Groups	Maximum stress (MPa) (MEAN±SD)	Type of group comparison	P values
Group-I	4.08±0.94	G-I with G-II	0.981
		G-I with G-III	0.922
		G-I with G-IV	0.954
Group-II	4.43±1.33	G-II with G-III	0.750
		G-II with G-IV	0.808
Group-III	3.53±1.36	G-III with G-IV	0.999
Group-IV	3.63±0.78		



Graph: 01- Mean maximum stress (MPa) values of different groups of materials



Graph: 02- Multiple comparison of mean maximum stress (MPa) values between the groups

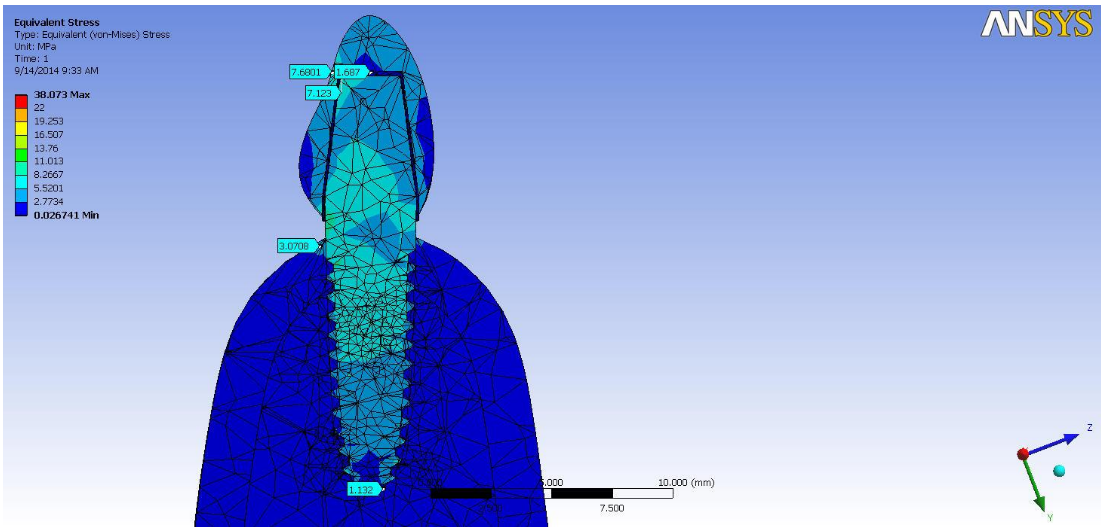


Fig: 10-Von mises stress Stress distribution around single piece titanium implants

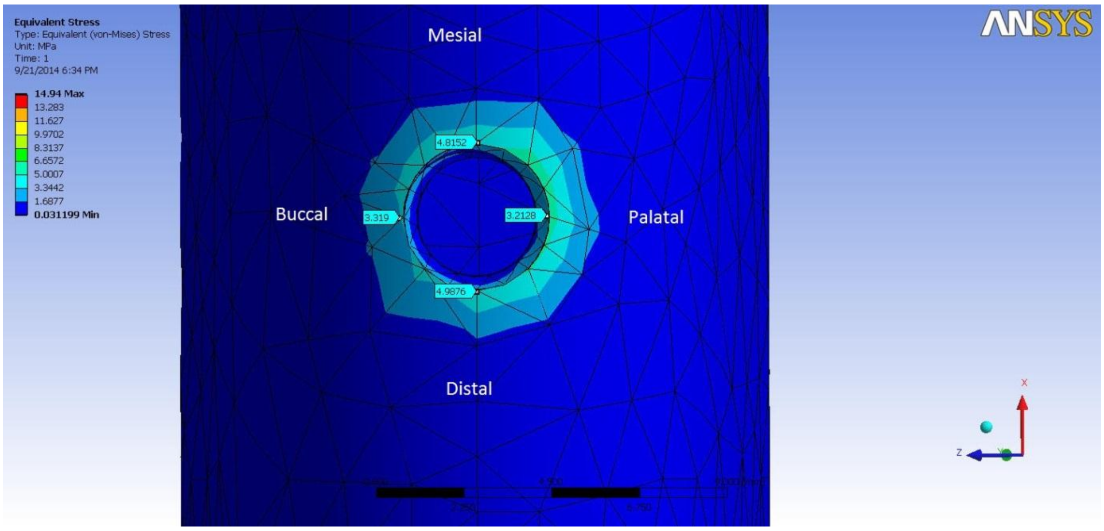


Fig: 11- Two dimensional view of Von mises stress Stress distribution around single piece titanium implants

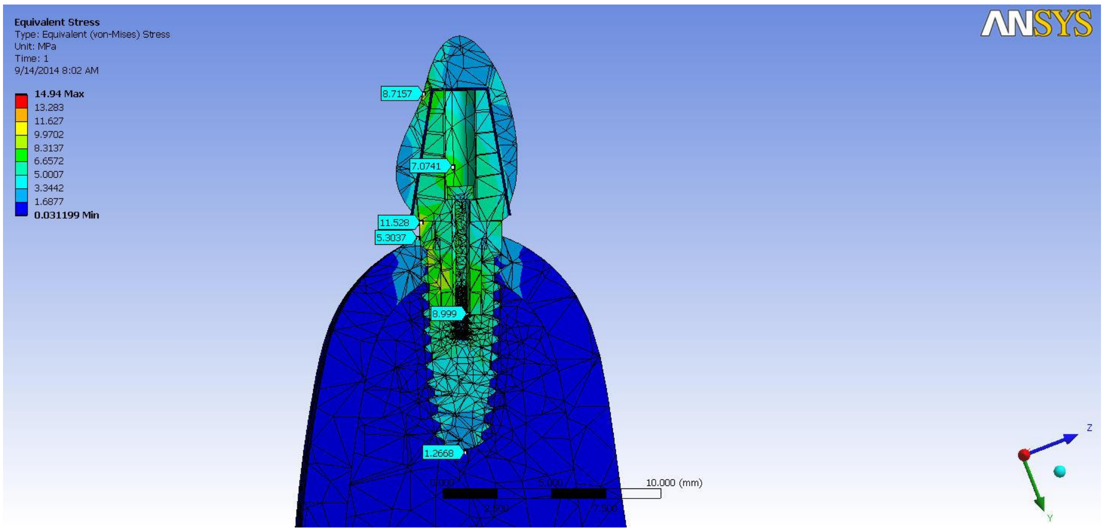


Fig: 12- Von mises stress distribution around two piece titanium implant

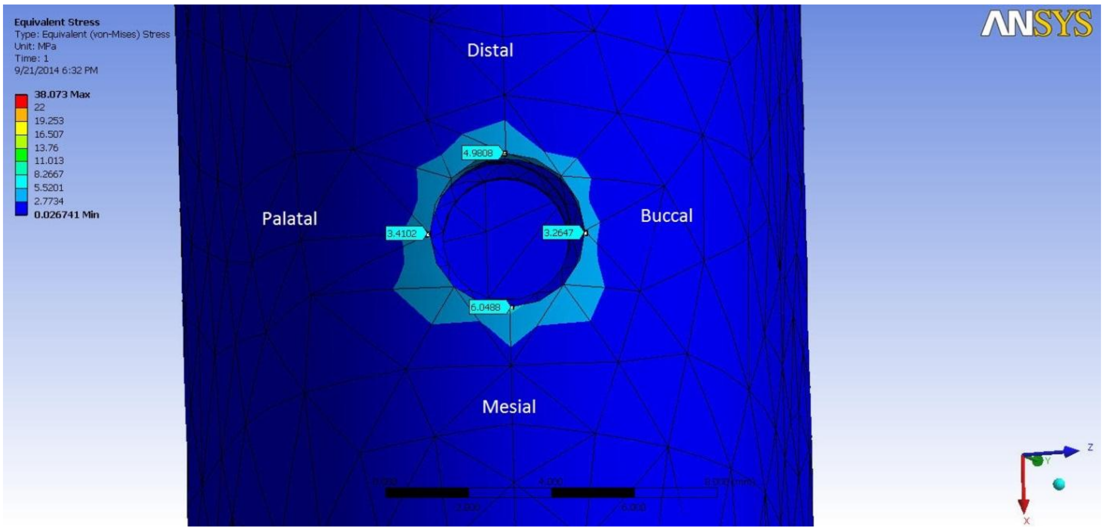


Fig: 13- Two dimensional view of Von mises stress distribution around two piece titanium implant

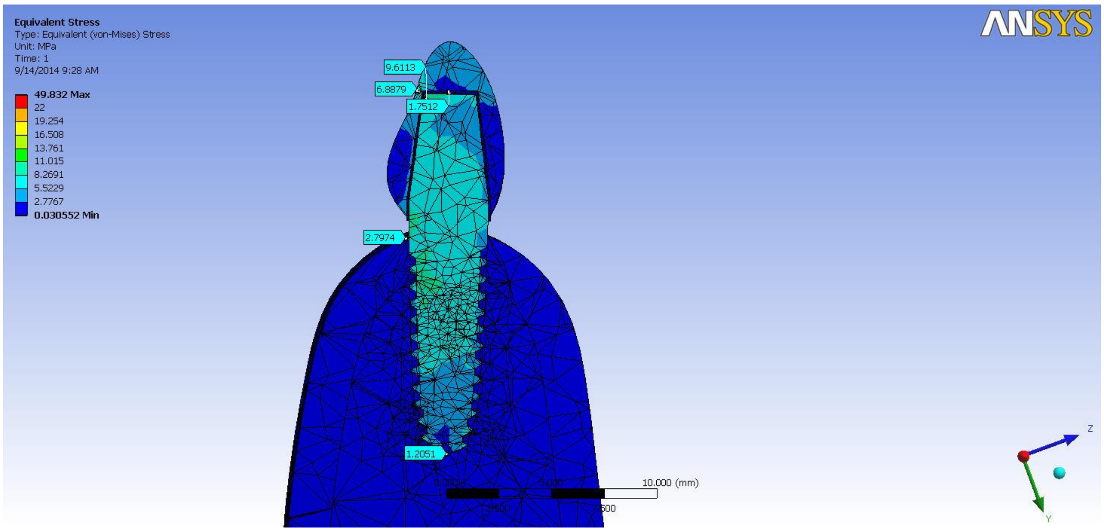


Fig: 14- Stress distribution around single piece Zirconia implant

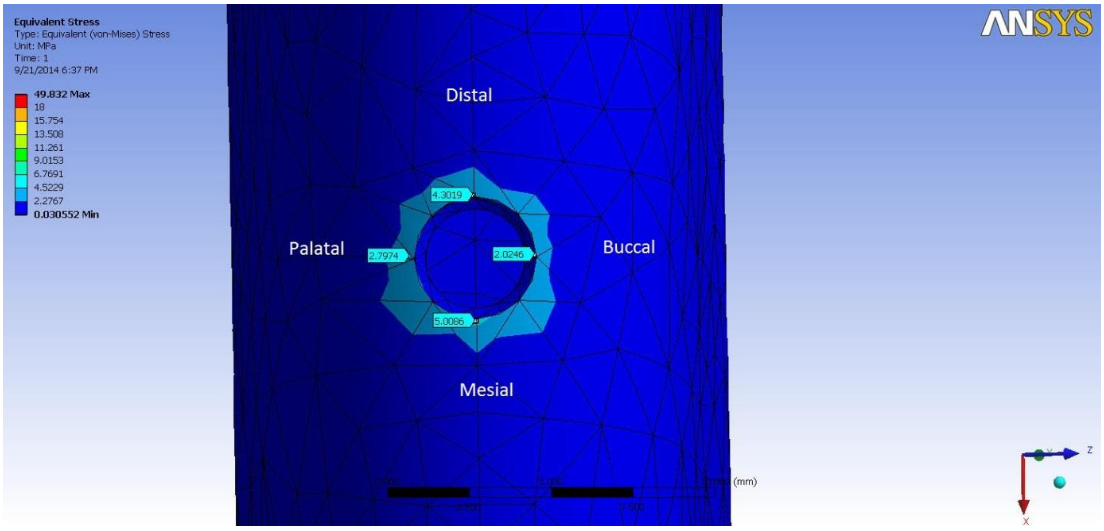


Fig: 15- Two dimensional view of single piece Zirconia implant

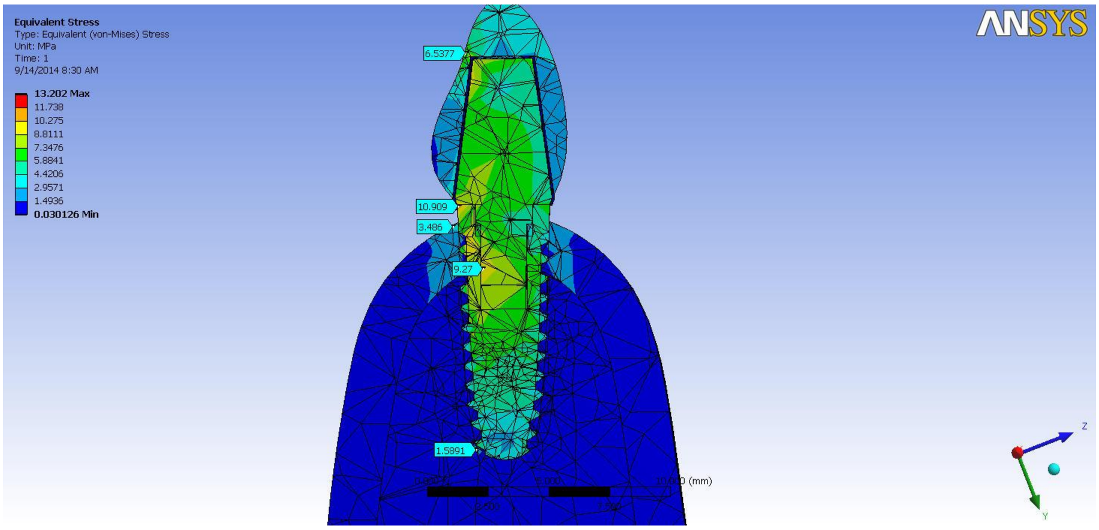


Fig: 16- Von mises stress distribution around two piece Zirconia implant

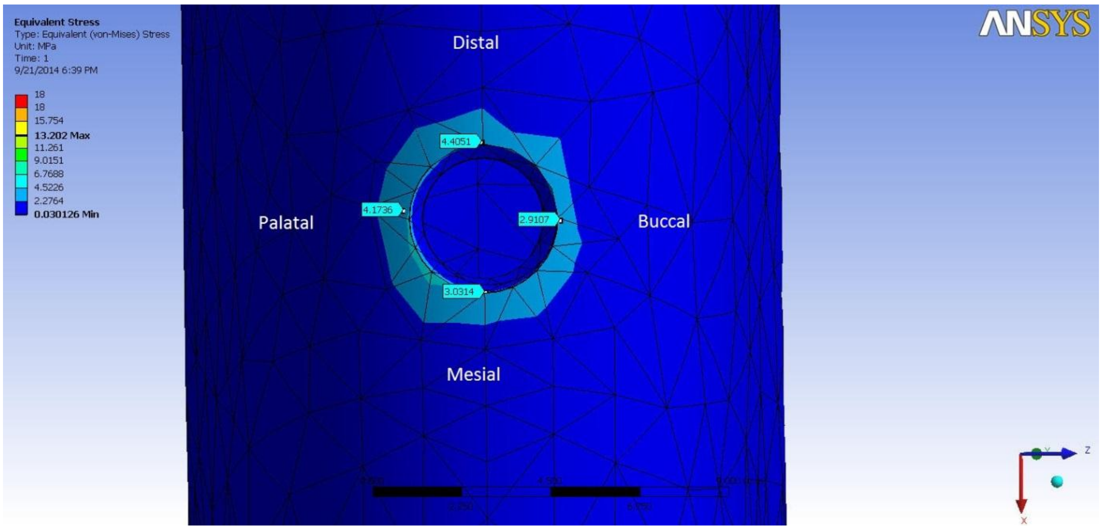


Fig: 17- Two dimensional view of stress distribution around two piece Zirconia implant

DISCUSSION

The main intention of this retrospective study was to find the stress distribution around single piece and two piece titanium and zirconia implants.

Dental implants have become a predictable treatment option for totally or partially edentulous patients. The high success rate of dental implants has changed the quality of life for many patients. Though several variables are responsible for successful implant osseointegration and its maintenance, the factors involved generally can be grouped as surgical, host related, implant or occlusion related factors. Implant placement is influenced by prosthodontic design, in general and available bone in particular and so it was logical to develop a prosthetic design that minimised stress concentration, alignment problems, and other complications. Osseointergrated dental implants function to transfer occlusal forces directly to surrounding biologic tissues and trajectories of these forces affect the bone remodelling around implants. Mechanical stresses can have both positive and negative influence on surrounding osteoid tissue as well as for the long term maintenance of oral implant osseointegration.[2]

Adell et al 1981 reported a success rate of 80 to 100 percent after fifteen year study of osseointergrated dental implants in the treatment of edentulous jaws.[65] Bone types in addition to bone volume have a more significant influence on stress on the bone.[35] Strength of bone is directly related to the density of bone. In denser bone there is less strain under a given load compared with soft bone. For compact bone, young’s modulus is ten times more than cancellous bone. The denser and stiffer the bone, less biomechanical mismatch to titanium or zirconia dental implants during loading. According to bone density, MISCH had classified Bone density in 1988 as D1, D2, D3 and D4. D1 bone is found in anterior mandible, D2 found in anterior and posterior maxilla. D3 is usually found in the anterior maxilla. D4 is found in posterior maxilla. The healing and progressive bone formation sequence for D4 bone requires more time than any other types, D1, D2 and, D3. D1 and D2 bone densities shows good initial stability and better osseointegration while D3 and D4 shows poor prognosis.[10,35] Optimum surgical technique to promote regenerative type of bone healing rather than reparative type of the bone healing is needed, that is using well sharpened and graded series of drills, adequate cooling to prevent bone necrosis, slow drill speed (less than 2000 rpm) tapping at a speed of 15 rpm with irrigation, and moderate power used for implant insertion.[66,35] D3 type bone model was used in this study as D3 type bone was noted in the anterior maxilla and our study was conducted in the anterior maxilla.

Metals like commercial pure titanium, nobium and possibly tantalum are most well accepted in bone as they are covered with a very adherent, corrosion resistant oxide layer. Titanium was considered in the study as titanium continues to be the first choice material in implant fabrication for treating partially or fully edentulous patients[.65] An oxide layer is formed spontaneously on the surface of titanium implants.[18] Alloying titanium with other metals can change the characteristics of surface and oxide layer which may result in altered tissue response. When exposed to air, titanium forms an oxide layer immediately in 10^{-9} seconds that reaches a thickness of 2 to 10nm in 1 second, thus providing corrosion resistance. The condition of oxide layer that is its chemical purity and surface cleanliness is of paramount importance for the biologic outcome of osseointegration[3]. Three different oxides are formed, that is TiO (Anastase), TiO2 (Rutile), Ti2O3 (Brookite). TiO2 is most stable and most commonly formed on titanium surface.[31] The oxide layer is self-healing, that is if surface is scratched or abraded during implant placement it re-passivates instantaneously. Also TiO2 layer exhibits low level of charge transfer, which is lowest among all metals. This is the main reason for its biocompatibility. Modulus of elasticity of titanium is 110 GPa and is 5- 6 times greater than bone. This helps in uniform stress distribution.

Zirconia implants were considered in the study as zirconia dental implants proved to be a viable alternative to titanium and showed better performance in anterior aesthetic zone.[27] Zirconia also has the ability to be milled into the shape of natural tooth root and be placed immediately following extraction, excellent biomechanical characteristics, biocompatibility and tooth like colour. Also reports say success rate of zirconia implant is more compared to titanium implants.[8,61]

Ceramics like calcium phosphate hydroxyapatite and various types of aluminium oxide are proved to be biocompatible, but insufficient documentation and very less clinical trials had made them to be used less commonly.[16] Previously, the development of ceramic-based implants using aluminium oxide (Al_2O_3) was attempted. However, despite this material's ability to osseointegrate, its mechanical properties could not withstand long-term physiologic loading, which led to its withdrawal from the market. With the introduction of zirconia, particularly yttrium-stabilized tetragonal polycrystalline zirconia (Y-TZP), interest in ceramics as a material of choice has been renewed. Zirconia (Zr) exhibits good physical and mechanical properties such as a high flexural strength (900 to 1200 MPa), hardness

(1200 Vickers), and Weibull modulus (10 to 12). Stress-induced transformation toughening is a unique characteristic of Y-TZP since it undergoes a phase transformation resulting in local volume expansion, therefore counteracting crack propagation.[6] Zirconium implants also showed high modulus of elasticity than titanium implants.[49]

Zirconia is a polycrystalline ceramic without any glass component. It is a polymorph that occurs in three forms, monoclinic (M), Cubic (C) and Tetragonal (T). Pure Zirconia at room temperature is monoclinic and stable till 1170 degree Celsius. Above this temperature it transforms itself to tetragonal and then further into cubic phase at 2370 degree Celsius. During cooling, a Tetragonal – Monoclinic transformation takes place at the temperature range of about 100 degree Celsius below 1070 degree Celsius. The phase transformation which takes place during cooling is associated with volume expansion of approximately 3-4 %.This means that pure zirconium oxide would burst due to volume increase of grains and tension.[7,8]

In late 1929, Ruff and co-workers demonstrated the possibility of stabilisation of C-phase at room temperature by adding small amount of CaO. The addition of stabilising oxides like CaO, MgO, Y2O3, to pure Zirconia allows generating multiphase materials known as partially stabilised Zirconia and in the process improves the mechanical and physical properties of the material. Tetragonal zirconia poly crystals (TZP) is characterised by its outstanding mechanical properties,in particular high bending strength and fracture toughness and a Young's modulus comparable to that of steel.[20] Compared to other zirconium it is the finest grained, mechanically highest grade, most densely packed structure. It results in extremely high component strength, extra-ordinary bending and tensile strength, fracture and chemical resistance. Oxide ceramics are equal to metals from mechanical standpoint, but biologically stronger. Zirconia implants also proved to be a viable alternative to titanium implants. Its potential for osseointegration and successful clinical use has been documented.[43]

Case reports on the clinical outcome of Zr implants showed favourable peri-implant marginal bone levels and soft tissue parameters in a short-term follow-up period of 1 to 2 year. A limited number of studies evaluated the loading response of zirconium implants and compared it to the stress distribution pattern of titanium implants.Threaded implants provide more functional area for stress distribution than cylindrical implants and provide better primary anchorage. V- Shaped, threads transfer the vertical forces in an angulated path and thus may not be as efficient in stress distribution as the square shaped threads. Longer the threads, better the primary stability.Shorter implants (10mm or less) are associated with increased primary bone loss.Wide diameter implants exert less stress on crestal bone as compared to narrow implants.[16]

As titanium and zirconia implants comes in one piece and two piece forms, they were considered in this study. One piece dental implants comes with implant and abutment manufactured as a single unit. They were introduced first in 1940s and subsequently manufactured in a variety of designs and materials over four decades of clinical use. In 1977, Branemark etal published a ten year implant study about two piece implants. This eclipsed the use of most one piece designs, slowly gaining acceptance through mainstream dentistry by 1990.

As dental implants acceptance grew, increased demands for shorter treatment time and improved aesthetics was primary concern. Reports about favourable outcome of immediate and early loading studies helped to renew clinical interest in one piece implant design for immediate provisionalisation (immediate and early loading). An one piece implant replicated the overall geometry of a two piece implant system, but one piece implant eliminated, potential abutment rotation, screw loosening, bacterial colonisation along the sub mucosal implant-abutment interfacial micro gap so that, one piece implants would offer some clinical benefits over two piece implant system.[57]

Unlike the conventional two piece implant design, the one piece implant offers several advantages like elimination of second stage surgery, use of interim removable partial denture, reduction in treatment cost. In two piece implant design, because of micro gap between implant abutment fixtures, the chance of plaque accumulation is greater.[7]

One piece implant design has a smooth metal surface at the crestal portion of the implant, which is easier to clean and collect less plaque than a rough surface. One piece tapered implant in the form of a threaded screw transmits axial tensile forces or compressive load and induces a component of compressive load in the bone – implant interface. One piece implants can be less invasive and can also offer improved primary stability. One piece is indicated generally in areas where there is insufficient bone in terms of width and height and also in cases of immediate implant placement in fresh extraction socket.[12] When two piece implants and one piece implant designs are compared, the stress concentration is more at the junction of abutment and implant fixture in two piece implant.[58] With one piece implant designs, the transmucosal part is incorporated into the implants, whereas in two piece implant design it is separate. One piece implants have an advantage of eliminating the need for reconnection of abutments, enabling the transmucosal surface to stay unaltered throughout the prosthetic procedure. Also one stage surgical procedure with no re-opening procedure will reduce the healing period time and the overall cost will also be reduced. The main disadvantage of one piece implants is it should be inserted exactly into the anatomical position. This is a critical factor in the esthetic zone.[51] Two piece implants can offer increased flexibility, with connections possible at bone level. Primary stability may therefore be improved and wound healing can be easier.

Two piece implants were designed earlier with prosthetic components that locate the interface between the implant and attached element component at the outer edge of implant platform. Two piece implants can offer increased flexibility, with connections possible at bone level. Primary stability may therefore be improved and wound healing can be easier. Two piece implants have problems like abutment screw loosening and abutment screw fracture after the prosthetic phase. Although contemporary one piece and two piece implant system may have similar gross external geometries, internal variations may result in very different pattern of load distribution. One piece implant system has a solid transition between the components, and two piece implants has a interfacial break between the implant and abutment. This may also be a cause for increased stress concentration in crestal bone region for two piece implants, but there is very little studies regarding this. Also it may be noted that due to decreased diameter of the screw in the body to head of screw transition may concentrate the stresses in this small region.[58]

Bone resorption with two piece implants is approximately 1.5mm -2mm.We can decrease this by changing the geometry of implant abutment interface. Two piece implants may be beneficial to avoid severe stress bone loss. Two piece implants may be used in cases where we need soft tissue augmentation and soft tissue connection is necessary and primary closure need to be obtained.[10]

Despite the great use of dental implants, many factors regarding its biomechanical aspects remain incompletely understood. In maintaining the bone implant interface, biomechanical factors play an important role. Major complication associated with dental implants has become restorative related, rather than surgery related. As we know implants lack the stress release associated with periodontal ligament, implant loading to restorative material and crestal bone remain potentially more damaging with implant supported restoration.[25] Extensive investigations are needed to establish and understand the correlation between marginal bone loss and occlusal forces, including the engineering principles, biomechanical relationship to the living tissues and the mechanical properties of bone surrounding implants. Bone resorption close to the first thread of osseointergrated implants is frequently observed during initial loading.[10] To achieve stable osseointegration for implant restoration, the generation of high stress concentration or high stress distribution in bone should be avoided, since the high level of stress concentration or distribution can induce severe resorption in the surrounding bone, leading to gradual loosening and, finally complete loss of the implant.[56]

Once implant is loaded the implant may become mobile within 6-18 months. This is called early loading failure by MISCH and JIVIDEN. Main cause is excessive stress for bio-implant interface. The magnitude of stress depends on two variables, Force magnitude, cross sectional areas over which the force is dissipated. Stress related conditions that affect the treatment planning in implant dentistry include the bone volume loss after tooth loss, complications of surgery, implant positioning, initial implant healing occlusal concepts, prosthesis fixation, component fracture and implant fracture. The crestal bone levels are dependent on the location of the implant abutment junction in relation to the bone crest. It has been demonstrated that when implant abutment junction is positioned deeper within the bone, crestal bone loss decreases.[10]

The role of the dental implant is to transfer the mechanical forces created during chewing to the supporting osseous tissues within the mandible and maxilla. It is of benefit to evaluate the effects of stresses exerted on the supporting bone as a result of the stress and strain fields around a fixture. Stress analysis test are used often to evaluate the load transmission from an implant to surrounding tissue in an effort to understand the biological failure. At present, there are no in vivo techniques that allow for an accurate study of stress, although numerous physical and theoretical methods are available to analyse stress distribution for complex structures, like finite element analysis and photo elasticity.

Bite forces may be defined as compressive, tensile, or shear forces. Compressive forces attempt to push materials towards each other. Tensile forces pull objects apart. Shear forces on implants causes sliding. The most detrimental forces that can increase the stress around implant-bone interface and prosthetic assembly are tensile and shear forces. These forces tend to harm material integrity and cause stress build-up. In general the implant –prosthetic unit can adapt to compressive forces. In actual mastication, the repeated pattern of cyclic forces transmits load through the restoration and dental implants to peri-implant bone. This generates different amounts of stress around the ridge and also in the prosthetic structure. However randomized cyclic forces are not stimulated therefore most finite element analysis study use static axial or non-axial forces. Non axial loads generate distinctive stress in the ridge especially in the cortical bone. The main remodelling differences between axial and non-axial loading are affected by horizontal component of resultant stress. The magnitude of bite force may change according to age, sex, dentualism, Para functional habits and may differ from anterior to posterior in the same mouth.[10]

Stress distribution in bone is a direct function of design. Dental implants mainly function by transferring occlusal forces to surrounding biologic tissues and the force affect the bone remodelling around oral implants. When mechanical stresses are applied to bone both positive and negative consequences occur in bone tissues. Bone is reported to function within a strain range of approximately 50- 100 (με). We should always design an implant so that it can distribute stresses to bone homogenously in an appropriate manner to support restorative function and encourage osseous attachment. Unlike natural teeth, osseointergrated implants ankylose with bone, without the periodontal ligament, which provides mechanoreceptors as well as shock absorbing function.[21] The crestal bone surrounding dental implants may act as fulcrum point for lever action when we apply force and this may lead to crestal bone loss. When we apply mechanical force it produces stress and strain in bone causing deformation of its structural arrangement.[65] Lots of studies were conducted using Finite Element Analysis, with major variations in the abilities of different implant designs to resist and distribute vertical and lateral occlusal load in bone. Implant design, load (magnitude and direction) boundary conditions, quality, mechanical properties and cortical thickness of bone all influenced bone stress levels. Vertical and transverse occlusal loads produce stress gradients in implant system and in the surrounding bone. The manner in which an implant system, transfer the resulting axial, off-axial forces and bending movements to the supporting bone directly affects the survival and long term crestal bone maintenance. Many different variables can affect load distribution, such as implant geometry and dimensions, material properties, surface characteristics, the percentage of bone to implant contact, bone volume, prosthesis type and load vector angle relative to implant axis.[61]

Bone tissues react to strain or deformation. Depending on the properties of the tissue, a given force may affect different bones or bone tissues differently. However, mechanically loaded bone adapts to the load promptly.[41] Maximum stresses were concentrated at implant neck when we apply force in comparison with trabecular bone, cortical bone usually has higher elastic modulus and more resistance to deformation. Cortical bone also has the ability to transfer stresses for this reason it can support lager amount of stresses than trabecular bone.[38]

For the implants, first principal stresses (the maximum tensile values) were considered to be more important because failure occurs when the tensile stresses are greater than or equal to the ultimate tensile strength of the material. In most FEA studies the bone –implant interface was assumed to be 100% bounded or completely osseointergrated. Evaluation of peri-implant stress in finite element analysis study is important for obtaining accurate treatment methods in implant dentistry. Implant and surrounding bone should be stressed within a certain range for dynamic physiological remodelling. If ideal functional forces are placed on a restoration the surrounding bone can adapt to the stresses and increase its density. Over load may cause high stresses at the crest of the ridge and result in bone resorption. Maintenance of bone density and stabilization is a direct result of ideal stress distribution. Under bite force localized stress occur at the prosthetic structure of bone. Stress is the magnitude of the internal forces acting within a deformable body. It is a measure of the average force per unit area of a surface with in body on which internal forces appear as a response to external forces directed on the body. Stress is often reported in scientific publication as MPa. Stress is directly proportional to the force and inversely proportional to the area across which force is applied. FEA has been widely used in all biomedical fields, especially for assessing stresses and strains in dental implants and surrounding structures. The von Mises stress values have been used to assess the stresses observed in bone implant interfaces along the long axes of the loaded implants. Von Mises stress values are defined as the combined effect of the three principal stress components resulting in a unique value, which is indicative of the onset of deformation for ductile materials, and have been used to interpret the critical stresses for bone remodelling and failure within the peri-implant bone.[38] In Finite Element Analysis studies microstrain is widely used as a method for measuring the load applied to bone. Finite element analysis is actually a mathematical analysis in which we get qualitative and quantitative solutions of interaction between, prosthesis, implant and surrounding bone. Finite element analysis is a complementary tool for exploring the detailed mechanical responses at work in implant dentistry.[7]

When a specific force is applied to the body, von Mises stress is the criterion used to determine the strain energy principles. There are three principal stresses that can be calculated at any point acting in the x,y,z directions. The von Mises criteria refers to a formula for combining these three stresses into an equivalent stress, which is then compared to the yield stress of the material. Frequently, different colours figures are used according to the amount of stress around peri-implant region and prosthetic structures. Stresses on each model are evaluated according to the stress values from low to high.

FEA studies have several advantages over clinical, preclinical and in vitro studies. Most importantly patient will not be harmed by the application of new materials and treatment modalities that have not been previously tested. Any living objects will not suffer from these biomechanical studies. However clinicians should be aware of the fact that all these applications are being performed on a computer, with critical limitations and assumptions that will clearly affect the applicability of the results to a real scenario. Confirming FEA results with mechanical tests, conventional clinical model analysis and preclinical tests are essential. It should not be forgotten that FEA results are helpful for clinical trials, but the results achieved from these studies are not valuable as clinical study results. However before beginning biochemical clinical trials, it would be wise to refer to FEA studies.[25]

The present study evaluates the stress distribution between single piece titanium and zirconium and two piece titanium and zirconium. The aim of this Three

Dimensional Finite Element Analysis was to compare the stress distribution around single-piece and two piece Titanium and Zirconium dental implants placed in an edentulous maxilla in the anterior region.

In this study we compared the stress distribution around single piece and two piece titanium and zirconia implants.Maxillary bone was modeled as a section of bone approximately the frontal part of maxilla, with cortical bone thickness of 1.5 mm enclosing a trabecular bone core.Properties approximating those D3 bone were used (D3 bone 350 -850 hounse field units). D3 bone has thin porous cortical bone on crest and fine trabecular bone within the ridge. Advantages of D3 bone is Osteotomy needs less than 10 seconds, bone tapping is eliminated, excellent blood supply for early healing, woven bone of 1.5 mm thickness was modeled around the implants with a bone implant contact of 65% to stimulate the immediately loaded situation. Bone block was modeled to be 15mm length and buccolingually 10mm wide to incorporate the implant dimension in it. Non –living mechanical structure such as implants, abutments, and restorations can be simulated in detail and can substantially influence the calculated stress strain values, similar to living structures.

These materials can be modeled digitally in FEA studies, determined to have transversely isotropic properties. In isotropic material, the relevant material properties are the same in all directions, resulting in only two independent material constants, Young’s modulus (MPa) also known as tensile modulus, is a quantity used to characterize material and is a measure of stiffness of an elastic material. The first step involved is modeling. The modeling was done using software called Pro/engineer. The Pro/engineer is a three dimensional software which is a product of

PARAMETRIC TECHNOLOGY CORPORATION. The software is among the very reliable and old parametric modeling package. Using the software, models can be made in very short time, editing of the models can be done with great ease and surfaces can be created to get exact shapes at microscopic levels. But the results achieved from these studies are not valuable as clinical study results. However before beginning biochemical clinical trials, it would be wise to refer to FEA studies.[25]

As an implant is complex in shape, for creating a model the computer tomography scan data is required. The implant is scanned at various sections at regular intervals of 0.5mm. These scanned images are then imported into Pro-Engineering software to various offset planes. Then manually in different sketch planes the curves are created along the implant to get the exact shape. Once the curve is created then lateral curves are created to have proper surface smoothness flow, to ensure proper surface lateral connectivity. This will help to get rid of wrinkles on the surfaces. Wrinkles on surface will greatly affect FEA model and can lead to wrong results. The models used in this study gave several assumptions regarding the simulated structures. The structures in this model were all assumed to be homogeneous, isotropic and to have linear elasticity. In this study 100% bone-to-implant contact was accepted, but histomorphometric data's indicate that there is never a 100% bone-to-implant interface. We should always keep in our mind the inherent limitations of finite element stress analysis to interpret the results.

From the curves, surfaces are created using a command called Boundaries. For this command the surface creation requires curves in the form of mesh that is curved in two directions, set of linear curves and a set of lateral curves need to be selected in order. From the surfaces, solid is generated. Once the implant is developed in similar fashion, other parts are created and assembled. This assembly is then exported to an analysis package. The export is through a bi-directionally understandable translator called IGES. This file format of export is understandable by most of the software. Axial load was applied. Since average masticatory force ranges from (100-300N), load value of 100 N was used in this study. FEA of the implant models were carried out using ANSYS WORK BENCH 10 SOFTWARE. Number of nodes and elements used in this study were approximately, 50,000& 35,000 respectively.Load was applied 2mm from the incisal edges of maxillary central incisor. The mean stress values developed around different implants at the cervical region are given in table: 2.

. Based on the results obtained, single piece zirconia implants developed less stress at the cervical region than single piece titanium and two piece zirconia developed less stress at cervical area than two piece titanium implants. When all the groups were compared statistically with each other, as in Table no:03 and in Graph no: 02 there exist no statistically significant difference between single piece titanium implants and single piece zirconium implants, and between two piece zirconium implants and two piece titanium implants. All groups have equally comparable effect that is stress distribution of zirconium is equally comparable to that of titanium.

According to a study conducted by Cehreli etal,[26] in force transmission of one and two piece morse taper oral implants-a nonlinear finite element analysis, the result showed the principal stress distribution around both single piece and two piece implants were similar under axial loading and there exist no significant difference between single piece and two piece implants, which is comparable with the study conducted above. According to the study conducted by Zeev Ormianer etal,[49] in stress and strain patterns of one piece and two piece implant systems in bone-a three dimensional finite element analysis, to determine whether one piece implants and two piece implants enhance or reduce stress concentration at cervical crestal bone region showed there would be no significant difference in load distribution between one piece and two piece implants.

According to the study conducted by Ralf–joachim kohal etal,[23] in Three dimensional computerised stress analysis of commercially pure Titanium and Yttrium –partially stabilized zirconia implants, to analyse stress distribution around implants made of commercially pure titanium and yttrium –partially stabilised zirconia implants, the results obtained showed, yttrium partially stabilized zirconia implants had very similar stress distribution to titanium implants which is comparable to the results obtained from the study conducted above.

According to the study conducted by Nicollo-mobillio etal,[63] in Experimental and Numeric Stress Analysis of Titanium and Zirconia One-Piece dental implants, to compare the stress in bone around zirconia and titanium implants, showed results that the stress generated by the two implants appeared to be very similar, this is comparable with the results obtained from the above conducted study.According to the study conducted by S Vishnu Rajendran etal,[66] in Stress analysis of Dental implants – a finite element analysis study, to reveal the stress distribution in implant-bone structure showed the maximum stress concentration occurs at the neck of the implants, which is similar to the above conducted study.

CONCLUSION

Conclusion:

From the finite element analysis method the following conclusion can be made,

1) Based on the above study, there exist no statistically significant difference in stress distribution between titanium and zirconia, single piece and two piece dental implants. Titanium and Zirconia implants are equally good in distributing stress.
2) Zirconia implants have stress distribution similar to commercially pure titanium implants and may be a viable alternative to titanium implants.

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